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WHAT DRIVES INVESTMENT IN TELECOMMUNICATIONS? THE ROLE OF
REGULATION, FIRMS' INTERNATIONALIZATION AND MARKET KNOWLEDGE

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Infrastructure and Transport

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ABSTRACT: The aim of this paper is to classify the firms operating in the European telecommunications market according to their degree of internationalization and market knowledge, and to test the effects of this classification and the existence of access regulation on infrastructure investment in European broadband markets. To do so, we construct a (unique) data set for the 27 European countries for the period 2002 to 2009. We estimate, by means of panel data techniques (and instrumental variables to control for any potential endogeneity problem), an investment equation for all firms and separate equations for entrant and incumbent firms. Our results show no significant relation between regulation and total investment. The variables capturing the degree of internationalization and market knowledge have a positive and significant effect on total investment, being a positive and significant effect on entrants' investment, but no significant impact on that of incumbent firms. This result indicates that, under the current regulatory framework, the firms that invest most are entrants with international experience, while the expansion of incumbents into other countries does not affect their investments in their home countries.

JEL Codes: L96, L51, F21, F23, D83

Keywords: Telecommunications, regulation, investment, internationalization, knowledge

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1. Introduction

Europe's broadband regulatory framework has been inspired by the concept of access regulation to the bottleneck elements of vertically integrated providers of infrastructure services. Hence, competitive access is seen as the instrument for eliminating the deadweight loss of monopoly and for establishing efficient service provision. To favour competitive entry, cost-based access pricing regimes have been adopted in most countries. The rationale behind this framework is that local loop access products will allow entrants to provide services with minimum direct investment while relying on the existing network developed by incumbents. Entrants are subsequently expected to invest, and to an increasing degree, in their own infrastructure.

The predicted results of such policies are twofold. On the one hand, new firms (entrants) can be expected to operate increasingly within more markets, while older firms holding monopolistic power (incumbents) are expected to expand their operations beyond their borders. Thus, telecommunications firms should increase the extent of their internationalization and their market knowledge. On the other hand, it is also expected that over time entrants will not require elements of the incumbent network and, therefore, will be able to compete by exploiting their own infrastructure. Both predictions have implications for the firms' investment decisions (i.e., broadband deployment) and, as such, for aggregate investment at the country level in the telecommunications sector. Within this framework, we analyse the effects of access regulation and different firm typologies (defined by the extent of their internationalization and market knowledge) in order to determine actual infrastructure investment behaviour in the European broadband market.

Previous studies identify different patterns of investment behaviour in such markets depending on whether firms are market incumbents or entrants (Wallsten and Hausladen, 2009 and Grajek and Roller, 2010). However, these authors (and all others, to the best of our knowledge) fail to account for all possible firm types participating in the market. Thus, in addition to classifying firms as incumbents or entrants, an incumbent firm in one country may also be an entrant in another, while an entrant may operate in several countries. Likewise, different investment behaviours can also be expected from this wider taxonomy of firms that also takes into account the extent of their international and knowledge dimensions.

On the one hand, the extent of a firm's internationalization, i.e., its international participation through investment in assets and/or control of activities in several markets, will afford certain advantages given, among others, the possibilities to exploit economies of scale and scope, to have enhanced power in standard-setting debates (of obvious relevance in a hi-tech industry such as telecommunications), and to increase long-term market capitalization, which favours the investment required by infrastructure sectors such as telecommunications.

On the other hand, a firm's market knowledge is a further dimension that needs to be considered alongside its internationalization. First, increasing internationalization implies that a firm can accumulate knowledge by operating in more than one country. Thus, overall market expansion can benefit from the knowledge acquired in other countries. Second, as well as reaping the benefits of internationalization, incumbents have a better knowledge of the market than that held by entrants. Given that incumbents are former monopolist operators, they will have accumulated years of experience and knowledge about customers, regulations and doing business in the local market. By considering these two characteristics of telecommunications firms (i.e., their internationalization and market knowledge), we

propose constructing a new typology of firms and examining its impact on broadband investment.

This article is organised as follows. Section 2 undertakes a review of the literature related to access regulation, internationalization and market knowledge. Section 3 outlines our empirical strategy and discusses data issues. Section 4 presents the estimations and results of our analysis. Finally, Section 5 concludes.

2. Drivers of Investment in Telecommunications: a Review of the Literature

In Europe, high-speed broadband Internet access is provided by two main technologies: DSL (Digital Subscriber Line) and cable. Although other access technologies are available (FTTH, WLL, Satellite and PLC), by July 2009, DSL and cable represented around 80 and 15% of broadband retail lines, respectively.¹ While the cable industry is not subject to access regulation in Europe,² its DSL markets are subject to a form of third-party access regulation, known as mandatory unbundling. Therefore, as it is the dominant technology in Europe's retail broadband market and because changes to the DSL regulatory framework have sought to promote broadband deployment through competition (EU Directive 2002/19/EC), DSL forms the focus of this study. Below, we review the economic literature dealing with the impact of access regulation and the impact of firms' internationalization and market knowledge on broadband investment.

2.1 Access Regulation

During 2002, unbundling regulation was implemented in Europe in order to ensure the entrance of new agents in the sector.³ With the aim of stimulating competition and achieving the desired effects in markets and among consumers, new entrants were provided with access to the incumbents' fixed-line infrastructure at the wholesale level. This new mandatory framework was set out in several EU Directives obliging Member States to introduce the measures within their national laws in a pre-determined period of time (albeit that various distinctions were made between countries). Thus, each Member State has taken steps towards implementing the new regulations with respect to each access type in accordance with the specific characteristics of their local markets.

The effects of mandatory unbundling in Europe have generated considerable debate. Its proponents claim that unbundling serves to encourage broadband deployment and to promote facility-based competition, while its opponents argue that it distorts entrants' make-or-buy decisions, impedes investment incentives and, as such, has been a failure.⁴ A leading question in this debate concerns the effects of mandatory unbundling on a firm's investment incentives. Given that this is the focus of our research, the following summary of the literature examines the findings of relevant studies.

The theoretical literature, conducted from a variety of approaches and examining the impact of access regulation on investment, does not provide policy makers with any clear-cut answers (Valletti, 2003). Most of the theoretical models presented therein assume exogenously determined positions for both incumbents and entrants in the market. As such,

¹ Estimation based on EC report (2009).

² In 2009, for the first time, access obligations were imposed on a cable network in Denmark (see EC, 2009).

³ Regulatory framework provided for under EU Directives 2002/19/EC, 2002/20/EC, and 2002/21/EC.

⁴ The literature review on broadband and investment regulation in Cambini and Jiang (2009) provides extensive coverage of this debate.

access regulation is viewed as a pro-competitive measure and an instrument for spurring investment. This reasoning underpins the “stepping stone” or “ladder of investment” theory proposed by Cave and Vogelsang (2003). This theory holds that allowing entrants to lease elements of the incumbents’ network with minimum direct investment at initial stages of competition acts as a catalyst for them to invest and create their own infrastructure. Based on analyses of these two firm types, such models analyse the impact of access regulation on investment (see, for example, De Bijl and Peitz, 2005, and Vareda, 2007).

Alternatively, some models rely on an endogenous determination of a firm’s position, reflecting its own actions and those of other firms. Firms compete with each other to determine their positions and, hence, infrastructure investment decisions are affected by access regulation. Examples of studies conducted from this approach include Gans and Williams (1999), Gans (2001) and Hori and Mizuno (2009). Gans and Williams (1999) show that an appropriately specified access price can result in socially optimal investment timing and one that, in all circumstances, is superior to a scenario without regulation. Gans (2001) confirms these results with the introduction of downstream competition. By contrast, Hori and Mizuno (2009), in examining the choice between service-based and facility-based competition, find that the former leads to delays in the construction of alternative infrastructure when entrants access the incumbent network.

Given this lack of consensus in the theoretical findings concerning the impact of access regulation on broadband investment, many empirical studies have sought to provide improved insights for policy implementation. The empirical literature examining this issue can, however, be divided in two strands: studies finding evidence in support of mandatory unbundling and studies that point in the opposite direction.

Based on an industry simulation⁵ on United Kingdom data, Christodoulou and Vlahous (2001) suggest that a mix of infrastructure and service competition, such as that promoted in the Netherlands,⁶ stimulates incumbent and entrant investment alike and offers better consumer benefits. The implication of these results for policy makers is that the introduction of “sunset clauses” provides new entrants with strong incentives to invest while allowing them to enter in service competition and acquire essential knowledge about their new market.

The OECD Report (2001) claims that, for its member states, “the evidence indicates that opening access networks, and network elements, to competitive forces increases investment and the pace of development”. Likewise, Wallsten (2007) tests the impact of regulation and demographic variables on broadband development in OECD countries for the period 1999-2003, explicitly taking into account different types of unbundling regulations. The author finds that extensive unbundling mandates and certain types of price regulation can reduce broadband investment incentives, although regulations ensuring easier interconnection with the incumbent can increase investment.

⁵ Industry simulation involves business strategy models at the firm level and, rather than seeking equilibrium solutions, offers insights to possible outcomes of strategic choices that companies might make.

⁶ The Dutch regulator, OPTA, proposed an approach that includes the introduction of “sunset clauses”. This meant the gradual introduction of a five-year transition period from tariffs based on historical costs to tariffs based on current costs in an attempt at stimulating competition in both the early stages and in later years. After the five-year period, the incumbent would, in principle, be free to set its tariffs on a commercial basis (Christodoulou and Vlahous, 2001).

Yet, the weight of empirical findings tends to lend greater support to the detractors of mandatory unbundling. Despite the fact that a large number of these studies draw on data for the United States, below we restrict our summary to the main findings within Europe, given that this is the framework in which we conduct our study.⁷

By comparing the diffusion of broadband access through intra-platform and service-based competition, Distaso et al. (2006) analyse the effects of mandatory unbundling on broadband deployment. Using data for 14 European countries for the period 2000-2004, they find inter-platform competition to be the main driver of broadband uptake, while competition in the market for DSL services does not play a significant role.

Hoffler (2007) studies the costs and benefits from infrastructure competition by estimating the welfare effects of broadband access competition between DSL and cable. The study draws on data for 16 Western European countries between 2000 and 2004. The author finds that infrastructure competition had a significant and positive impact on broadband penetration. However, when comparing the additional social surplus attributable to cable competition with that derived from cable investment, he concludes that, in the absence of significant positive externalities, infrastructure competition has not been welfare enhancing.

Friederiszick et al. (2008) analyse the relationship between entry regulation and infrastructure investment, drawing on data for 27 European countries between 1997 and 2006. Paying careful attention to the endogeneity problem of regulation (by applying instrumental variables), the authors report that entry regulation discourages infrastructure investment by entrants and that it has no effect on incumbent firms in the fixed-line telecommunication sector.⁸

Distaso et al. (2006) and Hoffler (2007) made early contributions to the debate on the effects of mandatory unbundling on broadband penetration. However, both studies only examine the two-year period immediately following the implementation of the new regulation. A longer period of time, such as the one adopted in our estimations, is needed to obtain a better appreciation of the consequences of unbundling on broadband uptake.

In short, empirical studies conducted in Europe provide conflicting evidence on the impact of access regulation on broadband investment and as such the debate remains ongoing.

2.2 Internationalization and Market Knowledge

Various studies point to different patterns of investment behaviour in broadband markets depending on the typology of operating firms, but to date this typological classification has been limited to that of market incumbents and entrants. Here, in addition, we propose classifying firms by their degree of internationalization and the extent of their market knowledge. We then seek to determine whether (and how) this new firm typology affects infrastructure investment decisions in the European broadband market.

Different patterns of behaviour expressed by incumbents and entrants have been described by Wallsten and Hausladen (2009) through the estimation of separate regressions for the two

⁷ Studies taking this line outside Europe include Jorde et al. (2000), Crandall and Singer (2003), Ingraham and Sidak (2003), Zarakas et al. (2005) and Jung et al. (2008); while examples of studies countering the ladder of investment theory in the US are Crandall, Ingraham and Singer (2004) and Hazlett and Bazelon (2005).

⁸ The authors focus primarily on telecommunication operators given, they argue, that cable has low rates of penetration in Europe.

firm types. Using a data set for 27 European countries over the period 2002 – 2007, they find a significant negative correlation between the number of unbundled DSL connections per capita and the number of fibre connections. They also confirm the negative impact of unbundling policies on new infrastructure investment (measured by the number of new fibre lines). Similarly, Grajek and Roller (2010), in a study of 20 European countries over the period 1997-2006, in which they examine just fixed-line operators, find that an increase in regulatory intensity decreases incumbents' investment but increases total investment across entrants. However, these results are based on the impact of access regulation on total investment summed over entrants, so when they focus solely on individual entrants they find that access regulation has a negative impact on their investment.

In line with these previous studies, we also consider differences between incumbents and entrants. However, additionally, the firm classification proposed here considers the possibility that the extent of a firm's internationalization and market knowledge may also affect its investment decisions. In general, to understand the motivations underpinning a firm's internationalization and its investment decisions we rely on arguments drawn from International Business Theory and Management Theory.

The eclectic paradigm of international production (Dunning, 1977, and Dunning and Lundan, 2007) is part of the International Business Theory⁹ with a three-component structure: ownership, location, and internalization. The ownership component explains how companies manage to obtain sustainable competitive advantage, analyzing their internal resources to correct their weaknesses and develop their potentials. The existence of assets is related to a firm's capacity to expand and stand out from its competitors. Among its tangible assets are economies of scale and patents, while its intangible assets include the firm's brands and reputation. The assets might, furthermore, be specific to a particular location (the location component) in terms of their origin and use, yet at the same time be available to all firms. These assets also include, therefore, the cultural, legal, political, financial and institutional environment in which they are deployed. Finally, the internalization component, with obvious links to Coase's (1960) transaction costs and Williamson's (1967) notion of a firm's boundaries, reflects that these boundaries should be kept as large as possible while it faces transaction costs. Therefore, from the resource base and transaction costs at the root of the ownership and internalization components, by expanding internationally a firm may obtain certain cost reductions and/or exploit its scale economies.

From another perspective, the strategic management literature views the internationalization as a form of diversification.¹⁰ As for firm's product diversification, firms invest internationally for several motives. Nachum and Zaheer (2005) labelled these motives as market seeking, efficiency seeking, resource seeking, export seeking, and knowledge seeking, each of which value different resource endowments in the host country. Thus, among others, firms may emphasize the potential for economies of scale in choosing target countries for internationalization. Essentially this is a decision by firms on how best to configure its activities internally, in line with the comparative advantage of different locations in order to maximize efficiency and reduce costs.

⁹ Other international business theories include the Uppsala model (Johanson and Vahlne, 1977 and 2009) and the internalization theory (Buckley and Casson, 1976, 2003 and 2009).

¹⁰ Even though studies use different labels as international diversification, international expansion, geographic diversification, globalization and multinationality all tend to refer to the same conduct; what we call the firm's internationalization.

Firms may invest internationally in an efficiency-seeking process (see Dunning and Lundan, 2007 and Nachum and Zaheer, 2005) and, hence, a positive relation can be expected between the degree of their internationalization and their investment in the host country. However, from a different perspective, it might be argued that as a part of this internationalization a firm's multi-market contacts can lead to collusive behaviour and, hence, deter a firm from investing (Bernheim and Whinston, 1990).

Additional insights are provided by Sarkar et al. (1999), who combine elements of International Business Theory and management theory to study the drivers of the internationalization of telecommunication service providers. The authors highlight that the role played by scale as an internationalization driver includes the enhanced negotiating power it affords over equipment suppliers, cost reductions through volume accumulations across country locations and market segments, an increase in long-term market capitalization, and the economies derived from the optimization of network design.

Within the context of internationalization, knowledge also plays an important role. Ghoshal (1987) claims that internationalization can promote the experience or internal learning capabilities of companies helping them innovate and meet future changes. The learning effect of internationalization comes from the higher volume of operations, which allows firms to accumulate knowledge while progressively reducing costs.

In addition to this international component, a firm's knowledge of a specific market is closely related to its original position in that market. Depending on whether the firm is an incumbent or entrant, its market knowledge will differ. Incumbents have a better knowledge of the local market than is the case of entrants, as the former have years of experience and valuable accumulated knowledge of that market (customers, regulations, doing business, etc.). This is especially true in markets that once were monopolies but which have been liberalized, such as the telecommunications market and the new markets that have emerged from it, such as the broadband market.

While it is true that incumbents have a better knowledge of the local market than is the case with entrants, it is also true that the global knowledge of some entrants may be as well very important, at least compared with other entrants. First, following the internationalization of knowledge argument, entrants (incumbents) can be expected to present different investment behaviour depending on the degree of their internationalization (i.e. the number of countries in which they operate). Second, the overall knowledge of an entrant (incumbent) can differ depending on its position in the international markets (whether it is an incumbent or an entrant in other countries).

The role of internationalization and market knowledge as drivers of investment can be summarized as follows. First, since firms may invest internationally in an efficiency-seeking process and exploit their scale economies, a positive relation is to be expected between the degree of internationalization of a firm and its investment in the host country. Second, incumbents and entrants have different levels of knowledge of the local market and this may result in different investment behaviours. And, third, it can also be expected different behaviour within the entrants and within the incumbents depending on their degree of internationalization and their respective positions in the international markets.

3. Empirical Strategy and Data Issues

In this section we present the empirical strategy and the data used in testing empirically the relevance of the investment drivers discussed in the previous section. Eq. (1) represents country i infrastructure investment at time t (Inv_{it}) as a function of the typology of firms (TF_{it}), the regulation (Reg_{it-1}) and our three control variables: inter-facility competition ($HHI_{inter_{it}}$), intra-facility competition ($HHI_{intra_{it}}$) and per capita Gross Domestic Product ($GDPpc_{it}$).

$$Inv_{it} = \alpha_1 TF_{it} + \alpha_2 Reg_{it-1} + \alpha_3 HHI_{inter_{it}} + \alpha_4 HHI_{intra_{it}} + \alpha_5 GDPpc_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (1)$$

We combine data from various sources to create an original panel data set for testing the drivers of investment in broadband for the 27 European countries over the period 2002-2009 (see Table 1 for the definitions and sources of the variables). Below we explain the variables used in Eq. (1).

Table 1: Definitions and data sources

Variable	Definition	Source
Dependent		
Inv_{it}	Investment measured as the change in infrastructure stock (penetration rate)	European Commission
$Inv_{inc_{it}}$	Investment by incumbent	
$Inv_{ent_{it}}$	Investment by entrant	
Typology of firm		
$TF_{Lin_{it}}$	Linear	Point Topic, NRAs and firms' annual reports
$TF_{Conv_{it}}$	Convex	
$TF_{Conc_{it}}$	Concave	
$TFInc_{Lin_{it}}$	Incumbent linear	
$TFInc_{Con_{it}}$	Incumbent concave	
$TFEnt_{Lin_{it}}$	Entrant linear	
$TFEnt_{Con_{it}}$	Entrant concave	
Regulation		
AR_{it-1}	Access Regulation Intensity (0-3)	Plaut Economic and NRAs
$Trans_{it-1}$	Transposition of Community Law in Information Society	European Commission Application of EU Law
$RegQ_{it-1}$	Regulatory Quality Index	World Bank
Competition		
$HHI_{inter_{it}}$	Herfindahl Inter-facility Index	Point Topic
$HHI_{intra_{it}}$	Herfindahl Intra-facility Index	
Income		
$GDPpc_{it}$	Per capita GDP (thousands €, 2000 prices)	Eurostat

Infrastructure investment

Due to the lack of firm level data regarding specific investment in broadband infrastructure, we use a country level approach in which investment is approximated by the change in the

stock of infrastructure. More precisely, following Roller and Waverman (2001) and Koutroumpis (2009), from a broadband infrastructure production function we construct our broadband infrastructure investment variable as shown in Eq. (2):

$$Inv_{it} = Ln\left(\frac{Pen_{it}}{Pen_{it-1}}\right), \quad (2)$$

where Pen_{it} (the DSL penetration rate, number of lines per capita) represents the stock of broadband infrastructure in country i at time t . Data on the number of lines by country are drawn from two reports on broadband access published by the European Commission, namely the Communication Committee's Working Documents on "Broadband access in the EU: situation at July 2007" and "Broadband access in the EU: situation at July 2009". These reports have been published twice a year since the implementation of mandatory unbundling in 2002. Data on population comes from Eurostat.

Typology of Firms

As outlined above, the extent of a firm's internationalization and knowledge (as an incumbent or entrant) will influence its investment decisions across countries and time. We expect that the higher the degree of internationalization and knowledge a firm possesses, the greater will be its level of investment in that country.

Given that our firm typology is in part based on the degree of internationalization, it is essential to know how it might be measured. Dörrenbacher (2000) proposes three categories of indicator of internationalization: structural, performance and attitudinal. Structural indicators are those that provide a picture of a firm's international network at a given point in time. Two examples of such an indicator would be, first, the number of countries in which the firm is present and, second, its foreign assets expressed as a percentage of its total assets. Performance indicators measure the success or failure of a firm's activities abroad measured in terms of turnover and operating income. Attitudinal indicators focus on how the firm views and treats its subsidiaries abroad. One such measure is the amount of international experience (in terms of the number of years living abroad) that senior managers have.

Although the literature offers many methods for measuring internationalization, some are obviously easier to apply than others. Specifically, the availability of data is a major influence on which of the measures are feasible and which are not; for this reason, in this study we use a variant of the structural indicator, namely the number of countries in which the firm is present.

We construct a country level measure of firm typology based on the extent of a firm's knowledge and internationalization. Firms have associated an internationalization-knowledge valuation (V_{if}) for each country and period. In associating this valuation with each firm, the firms need to be sorted; first, in terms of the extent of their market knowledge of country i (whether they are incumbents or entrants); second, by the degree of their internationalization (the number of countries they operate in besides country i); and, third, according to their role as incumbents of, or entrants in, those countries.

Finally, the valuation (V_{if}) obtained by firms (f) operating in country (i) is added for each period (t) to obtain the typology (TF_{it}) characterizing the firms in that country and period.

$$TF_{it} = \sum_{f=1}^n V_{itf} \quad f = \text{firms } \{1 \dots n\} \quad (3)$$

As we have no prior information informing us as to how the different valuations might relate to each other, we construct three typologies of firms based on different relations between the scores of the valuation: linear, convex, and concave.

As shown in Table 2, the highest valuations are assigned to the more experienced and internationalized firms; the lower valuations are assigned to firms that are market entrants in just one country. This valuation increases if the entrant operates in more than one country, the extent of the increase depending on its position there: the increase is only slight if the firm is an entrant, while the increase is more marked if it is an incumbent. This allows us to capture not only the distinct behaviour that is to be expected between entrants according to the extent of their internationalization, but also that according to their overall knowledge gained from their position in the international markets (as entrants or incumbents). The valuation of the incumbents is assigned analogously. The lowest valuation is assigned to an incumbent that operates in just one country, while the highest is assigned to an incumbent that is also incumbent in two or more countries and an entrant of another.¹¹

Table 2: Valuation of Firms' Internationalization and Market Knowledge

Internationalization and Market Knowledge	Valuation		
	Linear	Cov X ²	Con X ^{.5}
Entrant in country <i>i</i>	0.0500	0.0025	0.2236
Entrant in country <i>i</i> and one other country	0.1000	0.0100	0.3162
Entrant in country <i>i</i> and two other countries	0.1500	0.0225	0.3873
Entrant in country <i>i</i> and incumbent in another country	0.2000	0.0400	0.4472
Entrant in country <i>i</i> and in another country and incumbent in another country	0.2500	0.0625	0.5000
Entrant in country <i>i</i> and incumbent in two other countries	0.3000	0.0900	0.5477
Entrant in country <i>i</i> and in another country and incumbent in two other countries	0.3500	0.1225	0.5916
Entrant in country <i>i</i> and incumbent in more than two other countries	0.4000	0.1600	0.6325
Incumbent in country <i>i</i>	0.4500	0.2025	0.6708
Incumbent in country <i>i</i> and entrant in another country	0.5000	0.2500	0.7071
Incumbent in country <i>i</i> and entrant in two other countries	0.5500	0.3025	0.7416
Incumbent in country <i>i</i> and in another country	0.6000	0.3600	0.7746
Incumbent in country <i>i</i> and in another country and entrant in another country	0.6500	0.4225	0.8062
Incumbent in country <i>i</i> and in another country and entrant in two other countries	0.7000	0.4900	0.8367
Incumbent in country <i>i</i> and in more than two other countries	0.7500	0.5625	0.8660
Incumbent in country <i>i</i> and in more than two other countries and entrant in another country	0.8000	0.6400	0.8944

We use TF_{it} in the first group of estimations as an initial (aggregate) approximation of the impact of firm type on investment. In the second group of estimations, we separate each country's firms according to whether they are incumbents or entrants so as to take into account that the two behave differently because their knowledge of the local market differs. In other words, we estimate the following infrastructure investment equations for incumbent and entrant firms:

¹¹ All the typologies represented here are based on the casuistic derived from the observation of firms in the European DSL broadband market. Thus, feasible typologies that do not occur in the periods and countries examined in this study were not included. Data for the construction of this variable come from the information provided by Point Topic's Global Broadband Statistics, National Regulatory Agency reports and the annual reports of telecommunication companies.

$$Inv_Inc_{it} = \alpha_1 TF_Inc_{it} + \alpha_2 Reg_{it-1} + \alpha_3 HHI_inter_{it} + \alpha_4 HHI_intra_{it} + \alpha_5 GDPpc_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (4)$$

$$Inv_Ent_{it} = \alpha_1 TF_Ent_{it} + \alpha_2 Reg_{it-1} + \alpha_3 HHI_inter_{it} + \alpha_4 HHI_intra_{it} + \alpha_5 GDPpc_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (5)$$

As presented in Eq. (4) and Eq. (5), we differentiate between incumbents (TF_Inc_{it}) and entrants (TF_Ent_{it}) so as to analyse the impact of typology on each equation of investment behaviour. The valuation assignment within incumbents and within entrants, however, is maintained as in the general firm typology.¹² Hence, we focus on the effect that the degree of internationalization of a firm has on its investment decisions, but also on its overall knowledge gained from the positions it holds in international markets.¹³

Regulation

The relevance of regulation as a driver of broadband investment was reflected in the literature review. Normally, a firm's investment decisions are taken in line with strategic investment plans, within which annual investment levels for the forthcoming year are decided at the end of that current year (if there is no information regarding future changes in regulation). Thus, regulations that can affect investment decisions for the forthcoming year are those that come into effect at the end of the current year. In order to capture the fact that firms do not react immediately to regulation, in Eq. (1) we introduce the various regulatory variables lagged one period.¹⁴

Several studies of the European telecommunications markets use the Plaut Economic regulation index (either all or just some of its components) as a regulation indicator. Here, we also use it as our access regulation intensity variable. However, since we do not want our results to be dependent on a single regulation indicator, we perform our estimations using three different indicators: Access Regulation Intensity (AR_{it-1}), Transposition of Community Law in Information Society ($Trans_{it-1}$), and Regulatory Quality ($RegQ_{it-1}$). Below, we provide further details of these regulatory variables.

Access Regulation Intensity (AR_{it-1})

In an unbundled DSL network, market competitors can provide customers with broadband access using different means. These means are related to the unbundled network elements

¹² To allow comparisons between the results obtained for the incumbents and entrants, incumbent valuations were normalized (rescaled so as to have the same minimum value as the entrants). Thus, the ratings assigned to both, incumbents and entrants, are in the same range.

¹³ When a firm from one country decides to enter into another country, it could also take into account the institutional framework similarity between the origin and destiny countries (its market knowledge might be more useful in a country similar to its own). We could account for this fact by including two different variables separately (type of firm and institutional similarity) or by including one variable that is a weighted indicator of the typology of firm taking into account the institutional similarity. However in a country level analysis as we do, some cautions should be taken regarding the analysis of institutional similarity across countries. On one side, the variable capturing the existence of a similar institutional framework can be fixed over time or specific to a group of countries and, hence, be captured in the fixed effect variables. On the other side, the weighted index of typology of firm taking into account the institutional similarity aggregated a country level can distort the effect we are trying to observe with the variable type of firm, not being totally clear what is the effect captured by the estimated parameters.

¹⁴ The introduction of the regulatory variables lagged one period also allows us to avoid the possible endogeneity problems mentioned above.

(UNEs) and represent the different types of access that the entrants have to the incumbent network.

The access regulation intensity variable is compound by the regulation of each access type (full ULL, shared and bitstream). For each type of access, the variable represents whether access regulation exists or not. Therefore, it takes the value of 1 when it exists and 0 otherwise. The access regulation intensity variable in a country i during period t is the sum of the access regulations to the three access types. Hence, it takes discrete values between 0 and 3:

$$AR_{it-1} = ULL_{it-1} + Share_{it-1} + Bitstream_{it-1} \quad (6)$$

Note that once the access regulation has been implemented to an access type in a country, it will be maintained for all successive periods. Data on access regulation for these three types of access come from the Plaut Economic regulation index (Zenhäusern et al., 2007) and are updated as far as 2009 with information from the National Regulatory Agency reports and the European Commission's Working Documents.

Transposition of Community Law in the Information Society (Trans_{it-1})

Much of European regulation law takes the form of Directives that set out general rules and provisions, but which leave Member States the choice as to how to implement them. Primary responsibility for applying EU law lies with the national administrations in the Member States. From the Secretariat General of the European Commission we obtained data on the percentage of Directives implemented (by Member State and sector) showing the link between the provisions in EU Directives and national rules. The sector classification related to telecommunications is that of the "Information Society".

Our variable, *Trans_{it-1}* captures the percentage of Directives associated with telecommunications that have been implemented in a country in each period. Since the access regulation is contained in EU Directives and the Member States must transpose these Directives to national laws in a pre-determined period of time, the *Trans_{it-1}* variable, though less specific, can be seen as analogous to the access regulation variable.

Regulatory Quality (RegQ_{it-1})

From a broader perspective, regulation extends beyond specific measures such as mandatory unbundling; hence, we attempt to validate our results by accounting for the quality of regulation. Regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit, and promote, private sector development. Our regulatory quality variable (*RegQ_{it-1}*) is a World Bank index built at the country level. It is measured in units ranging from -2.5 to 2.5, with higher values corresponding to higher levels of quality.

Competition

To capture the effects of competition at the retail level, we introduce two Herfindahl indexes (HHI) for each country and period in Eq. (1): one for intra-facility competition (*HHI_{intra;it}*) within the DSL network (full ULL, shared-access, bitstream access and resale) and one for inter-facility competition (*HHI_{inter;it}*) between networks (DSL, cable, FTTx and wireless). A Herfindahl index measures the degree of concentration of the market, and is defined as the

sum of the squares of a firm's (or networks in the case of inter-facility) market shares. Data for the construction of these indexes are taken from the information provided by Point Topic's Global Broadband Statistics.

Previous studies of broadband penetration and diffusion have also controlled for intra-facility and inter-facility competition effects. In the case of intra-facility competition, Bouckaert et al., 2010 find a negative effect, while Distaso et al. (2006) report an insignificant effect. In the case of inter-facility competition, while Bouckaert et al. (2010), Hoffler, (2007) and Distaso et al. (2006) find a positive effect, Gruber and Koutoumpis (2011) report a negative effect.

Income

We use per capita Gross Domestic Product ($GDP_{pc_{it}}$) as our income control variable. Previous studies in the literature on economic growth report a positive relationship between broadband penetration and economic growth (Koutroumpis, 2009 and Czenrich et al., 2011). Yet, broadband studies, such as Grajek and Roller (2010) and Distaso et al. (2006), which used income as a control variable, find no significant effect on either investment or penetration. To avoid possible problems of endogeneity from employing this variable, we use the lag of the GDP_{pc} as an instrument in our instrumental variable estimations.¹⁵ The data on $GDP_{pc_{it}}$ are from Eurostat. Table 3 contains the summary statistics of the dataset used in this study.

Table 3: Summary Statistics.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Inv_{it}	161	0.4927	0.6100	-1.2054	4.1540
$Inv_{inc_{it}}$	159	0.4392	0.5313	-1.2175	3.5285
$Inv_{ent_{it}}$	154	0.5805	0.8559	-2.0796	4.4397
$TF_{Lin_{it}}$	216	0.6888	0.3787	0.0000	2.0500
$TF_{Conv_{it}}$	216	0.3300	0.1974	0.0000	0.9025
$TF_{Conc_{it}}$	216	1.2320	0.8256	0.0000	4.0424
$TFInc_{Lin_{it}}$	216	0.1451	0.1337	0.0000	0.4000
$TFInc_{Conv_{it}}$	216	0.0388	0.0522	0.0000	0.1600
$TFInc_{Conc_{it}}$	216	0.3327	0.1859	0.0000	0.6325
$TFEnt_{Lin_{it}}$	216	0.1775	0.2803	0.0000	1.2500
$TFEnt_{Conv_{it}}$	216	0.0287	0.0633	0.0000	0.3175
$TFEnt_{Conc_{it}}$	216	0.5519	0.7430	0.0000	3.1479
AR_{it-1}	189	2.1587	0.9710	0.0000	3.0000
$Trans_{it-1}$	161	0.9755	0.0658	0.6842	1.0000
$RegQ_{it-1}$	189	1.2372	0.3861	-0.1000	1.8900
$HHI_{inter_{it}}$	201	0.6421	0.1956	0.3202	1.0000
$HHI_{intra_{it}}$	201	0.8046	0.2216	0.2255	1.0000
$\ln GDP_{pc_{it}}$	216	2.6293	0.8427	0.6620	4.1222

¹⁵ The endogeneity in this case derives from the possibility of spillovers generated by broadband networks that might result in externalities in other sectors of the economy, thus affecting the country's GDP (see Koutroumpis, 2009). By adopting the instrumental variables approach applied in this study, our aim is to avoid problems of simultaneity bias and spurious correlation deriving from the possible endogeneity problems.

4. Estimation and Results

In order to analyse the impact of regulation and firm typology on infrastructure investment we perform two groups of estimations. The first group seeks to evaluate the effect of regulation and firm typology on investment (Eq. 1) using the general typology for all firms. We are particularly interested in testing whether different typologies of firm operating in a country influence the level of investment in that country. In the second group of estimations, to obtain a better understanding of the drivers of investment, we evaluate the investments of incumbents (Eq. 4) and entrants (Eq. 5) separately. In both sets of estimations we control for country and time fixed effects.

4.1 Results I: all firms

First, we estimate Eq. (1) by means of panel data techniques and report the results in Table 4. To avoid possible endogeneity problems of the variable GDP per capita we make use of the instrumental variables (IV) method (results are presented in Table 5). Since our equations are exactly identified (the number of instruments equals the number of endogenous regressors), we are unable to test statistically for overidentification of all instruments (i.e. instrument exogeneity). However, we test for weak instruments with the *F*-statistics from first-stage regressions following the rule of thumb (see Stock and Watson, 2007). Our results show that weak identification is not a problem in our estimations, hence validating the relevance of our instruments.

Overall, the results from the estimations of Eq. (1) support a positive relationship between firm typology and infrastructure investment. When controlling by country and time fixed effects, the variable capturing the type of firm operating in the market, constructed for both the linear and the concave case, is positive and significant (see Table 4 and Table 5). These results support the hypothesis of a firm's internationalization and market knowledge acting as drivers of investment in the European broadband market.¹⁶ Moreover, our estimates indicate that when one firm enters into a country, the investment (increase in the stock of infrastructure) will be between 3.3% and 3.5% higher if the firm is also entrant in another country than if it is the first country in which the firm operates.¹⁷ Although firm level information would be needed to confirm these results, they seem to reflect the fact that firms invest internationally as part of an efficiency-seeking process or to exploit their scale economies. Furthermore, the relevance of international market knowledge for investment decisions seems to be important. This last point is evaluated in the following estimations in which we analyse the impact on investment according to the type of firms in a country, be they incumbents or entrants.

As for the effects of regulation on investment, none of the three regulatory variables (access regulation intensity, regulatory quality and transposition to community law) are significant at an acceptable confidence level across all estimated specifications. Although these results are highly consistent, they must be interpreted with caution. Since the estimated effect is for

¹⁶ Even though none of the previous studies takes it into account, it seems reasonable to expect that firms' investment decision in broadband might respond to the profitability that they may obtain when investing in a country. Thus, to control for profitability we have introduced as an additional control variable the (sectoral) telecommunication gross operating surplus/turnover rate from Eurostat. Results for those estimations show no significant effect coming from country profitability, and all other variables remain largely unchanged. One explanation for these results could be the slightly change of the sector profitability rate in the countries covered in this study, being its effect mainly captured, then, by the country fixed effect.

¹⁷ From the semi-log linear function nature of Eq. (1) we used finite-difference methods to compute the marginal effect coming from a change on the typology of firms participating in the markets.

total aggregate infrastructure investment (ignoring differences between incumbents and entrants), from an aggregate country point of view the implementation of some sectoral regulatory policies seems to have no effect on investment incentives.¹⁸

Table 4: Panel data estimates with country and time fixed effect. Dependent variable Inv_{it}

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Typology of Firm									
TF_Lin_{it}	0.678*	0.654*	0.684*						
	(0.388)	(0.372)	(0.379)						
TF_Conv_{it}				0.741	0.665	0.677			
				(0.654)	(0.593)	(0.601)			
TF_Con_{it}							0.273	0.260	0.275
							(0.173)	(0.166)	(0.169)
Regulation									
AR_{it-1}	-0.065			-0.070			-0.060		
	(0.080)			(0.087)			(0.081)		
$RegQ_{it-1}$		0.502			0.540			0.474	
		(0.636)			(0.661)			(0.629)	
$Trans_{it-1}$			-0.713			-0.651			-0.710
			(0.553)			(0.597)			(0.556)
Competition									
HHI_inter_{it}	2.009	2.096	2.167	1.844	1.939	1.989	1.874	1.959	2.020
	(1.331)	(1.350)	(1.334)	(1.450)	(1.470)	(1.451)	(1.403)	(1.424)	(1.403)
HHI_intra_{it}	1.480**	1.455**	1.291**	1.076	1.062	0.889	1.580*	1.546**	1.394**
	(0.702)	(0.663)	(0.588)	(0.640)	(0.626)	(0.550)	(0.794)	(0.747)	(0.675)
Income									
$\ln(GDPpc_{it})$	-0.420	-0.574	-1.163	-0.427	-0.599	-1.184	-0.544	-0.684	-1.249
	(1.288)	(1.288)	(1.376)	(1.360)	(1.344)	(1.430)	(1.271)	(1.281)	(1.391)
Constant									
	-0.634	-1.040	2.024	0.023	-0.399	2.686	-0.531	-0.873	2.071
	(4.206)	(4.307)	(4.508)	(4.454)	(4.621)	(4.808)	(4.305)	(4.475)	(4.587)
Observations	161	161	159	161	161	159	161	161	159
R-squared	0.448	0.449	0.456	0.431	0.433	0.437	0.442	0.442	0.449
Number of id	27	27	27	27	27	27	27	27	27

Note: Robust standard errors are clustered by country

Table 5: Panel data IV estimates with country and time fixed effect. Dependent variable Inv_{it}

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Typology of Firm									
TF_Lin_{it}	0.693*	0.655*	0.684*						
	(0.365)	(0.346)	(0.353)						
TF_Conv_{it}				0.795	0.671	0.681			
				(0.619)	(0.545)	(0.552)			
TF_Con_{it}							0.275*	0.260*	0.275*
							(0.166)	(0.158)	(0.160)
Regulation									
AR_{it-1}	-0.088			-0.097			-0.087		
	(0.081)			(0.087)			(0.086)		
$RegQ_{it-1}$		0.510			0.554			0.493	
		(0.578)			(0.602)			(0.573)	
$Trans_{it-1}$			-0.711			-0.662			-0.726
			(0.503)			(0.551)			(0.507)
Competition									
HHI_inter_{it}	2.331	2.147	2.157	2.204	2.024	2.036	2.248	2.071	2.084
	(1.465)	(1.501)	(1.523)	(1.574)	(1.631)	(1.653)	(1.549)	(1.581)	(1.607)
HHI_intra_{it}	1.448**	1.449**	1.292**	1.031*	1.050*	0.884*	1.535**	1.530**	1.387**
	(0.670)	(0.645)	(0.567)	(0.603)	(0.600)	(0.518)	(0.758)	(0.727)	(0.648)
Income									
$\ln(GDPpc_{it})$	0.696	-0.425	-1.191	0.837	-0.349	-1.028	0.756	-0.358	-1.040
	(1.595)	(1.641)	(2.006)	(1.631)	(1.708)	(2.077)	(1.662)	(1.698)	(2.104)
Observations	161	161	159	161	161	159	161	161	159
R-squared	0.445	0.449	0.456	0.427	0.432	0.437	0.437	0.442	0.449
Number of id	27	27	27	27	27	27	27	27	27
F-statistic	29.70	90.51	43.48	40.38	125.00	56.33	26.62	82.25	39.43

Note: see Table 4

¹⁸ When we control by country fixed effect (without the time effect), the transposition of community law is significant and negative. Therefore, if we do not take into account the time component, the effect of regulation, if any, would be negative.

Of the additional control variables, the intra-facility competition results are in line with those of Bouckaert et al. (2010). The variable is positive and significant in most cases, thus, the higher the competition within the DSL facility, the lower the investment in DSL. At the same time, the inter-facility competition variable is not significant at any acceptable confidence level across estimations. Thus, at the aggregate country level, changes in the distribution of the respective market shares enjoyed by DSL and alternative technologies have no significant effects on DSL infrastructure investment. The following estimations provide a more detailed examination of the effects derived from competition variables¹⁹.

Finally, GDP per capita does not have a significant effect on investment across all estimated specifications. These results are in line with those of Grajek and Roller (2010) and Distaso et al. (2006), who also used income as a control variable and found no significant effect.

4.2 Results II: entrant vs. incumbent firms

Following our empirical strategy, we estimate Eq. (4) and Eq. (5) by means of panel data techniques (Table 6) and with IV (Table 7) separately by entrant and incumbent firms. To take into account the differences in their infrastructure investment behaviour, we separated incumbents from entrants. These more specific estimations allow us to obtain a better understanding of incumbents and entrants investment decisions.

When investment drivers are analysed separately in this way, interesting patterns emerge. In the case of entrant firms, the variable capturing the typology of firm is generally positive and, more specifically, the convex version of the variable is significant across specification and estimation methods. By contrast, for incumbents this variable is not significant in any estimation. This last result points out that the expansion of incumbents to other countries does not seem to influence their infrastructure investment decisions in their original countries.²⁰

Our results on infrastructure investment by entrants indicate that when a firm enters into a country, the increase in investment will be between 1.9% and 2.0% higher if the firm entering is also entrant in another country instead of being the first country in which operates. Furthermore, when the firm entering is also incumbent in another country, the estimated increase in the infrastructure investment will be between 7.7% and 8.1% higher than if it was only entrant in another country. These results might reflect the fact that the entrants who invest more are those who have operations internationally and, probably, they are incumbents in other countries, which means they have a broader knowledge of telecommunication markets.

In general, the non significant effects of regulation on investment are consistent with those found in previous section estimations. For incumbent firms, the results do not differ: regulation variables are not significant at an acceptable confidence level across all estimated specifications. However, in the case of entrants, our findings are not so clear cut: regulation seems to have no effect, and where there is some, it tends to be negative. While access regulation and regulatory quality variables are not significant in any of the cases, the

¹⁹ We also consider that it can be a source of concern the possible endogeneity coming from the intra-facility competition. However, endogeneity tests (by difference-in-Sargan statistic) on this variable, confirm us that intra-facility competition variable can actually be treated as exogenous.

²⁰ When we control by country fixed effects, in terms of firm typology, entrant firms are positive and significant, while incumbents are, in most cases, negative and significant. Therefore, if incumbent firms have an effect, it is negative.

transposition to community law regulation variable is negative and significant. This negative effect on an entrant's infrastructure investment might reflect the fact that the transposition of EU Directives would have facilitated the use of the incumbent infrastructure, and so the level of investment by entrants falls.

The separate infrastructure investment estimation by incumbents and entrants also provides us with interesting results regarding market competition. In the case of entrants, the relation between intra-facility competition and investment parallels that of the aggregate estimations. The positive relation between intra-facility concentration and investment by entrants may be a result of the non-linearity in the relationship between competition and investment.²¹ Entrants might gain in their market share by using incumbent infrastructure, and so increases in competition are not accompanied by investment (new lines) but rather by subscribers (connections) switching from incumbents to entrants.

While intra-facility has no significant effect on the infrastructure investment of incumbents, the inter-facility competition, which gains significance in panel IV estimates, shows a positive effect. These results are consistent with Gruber and Koutoumpis (2011) who find a negative effect of inter-facility competition on broadband diffusion. Finally, as in previous estimations, GDP per capita does not have a significant effect on investment across all estimated specifications.

²¹ We test for a non-monotonic relation between competition and investment by introducing an additional quadratic term (HHI-Intra^2). Results for these estimations suggest a U-shaped relation between concentration and investment.

Table 6: Panel data estimates with country and time fixed effect. Dependent variables Inv_ent_{it} and Inv_inc_{it}

	Entrants									Incumbents									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
Typology of Firm																			
TF_Lin_{it}	0.702 (0.429)	0.721 (0.433)	0.753 (0.446)							-0.133 (0.614)	-0.155 (0.571)	-0.177 (0.584)							
TF_Conv_{it}				2.492* (1.417)	2.490* (1.440)	2.567* (1.462)							0.125 (1.468)	0.050 (1.323)	0.079 (1.373)				
TF_Con_{it}							0.238 (0.190)	0.254 (0.188)	0.267 (0.199)								-0.198 (0.500)	-0.211 (0.471)	-0.233 (0.480)
Regulation																			
AR_{it-1}	0.016 (0.074)			0.022 (0.075)			0.010 (0.073)			-0.006 (0.062)			-0.010 (0.063)				-0.003 (0.062)		
$RegQ_{it-1}$		-0.801 (0.811)			-0.750 (0.810)			-0.827 (0.822)			0.208 (0.533)			0.203 (0.529)				0.211 (0.535)	
$Trans_{it-1}$			-2.539* (1.239)			-2.488* (1.224)			-2.541* (1.237)			-0.085 (0.470)			-0.081 (0.467)			-0.090 (0.472)	
Competition																			
HHI_inter_{it}	1.678 (1.970)	1.611 (1.994)	1.745 (1.932)	1.868 (1.987)	1.794 (2.027)	1.937 (1.974)	1.429 (2.003)	1.358 (2.021)	1.466 (1.955)	2.298 (1.511)	2.313 (1.522)	2.314 (1.504)	2.282 (1.507)	2.304 (1.515)	2.304 (1.500)	2.308 (1.513)	2.321 (1.522)	2.321 (1.505)	
HHI_intra_{it}	1.307* (0.669)	1.306* (0.673)	1.045 (0.639)	1.152 (0.696)	1.139 (0.697)	0.867 (0.681)	1.267* (0.681)	1.282* (0.685)	1.029 (0.652)	0.515 (0.398)	0.522 (0.406)	0.445 (0.405)	0.505 (0.397)	0.514 (0.404)	0.434 (0.404)	0.525 (0.401)	0.532 (0.408)	0.454 (0.408)	
Income																			
$Ln\ GDPpc_{it}$	-1.049 (1.720)	-1.165 (1.851)	-0.082 (1.658)	-1.124 (1.700)	-1.211 (1.844)	-0.199 (1.648)	-1.029 (1.754)	-1.172 (1.866)	-0.016 (1.673)	-0.673 (1.504)	-0.651 (1.449)	-1.106 (1.549)	-0.639 (1.502)	-0.636 (1.442)	-1.085 (1.540)	-0.698 (1.501)	-0.665 (1.449)	-1.124 (1.554)	
Constant	1.917 (5.188)	3.297 (6.469)	1505 (5.265)	2.071 (5.145)	3.427 (6.455)	1.868 (5.259)	1.541 (5.388)	3.042 (6.571)	1.284 (5.452)	0.773 (4.850)	0.405 (5.091)	2.132 (5.080)	0.681 (4.832)	0.363 (5.067)	2.058 (5.042)	0.875 (4.883)	0.482 (5.126)	2.232 (5.129)	
Obs	154	154	152	154	154	152	154	154	152	159	159	157	159	159	157	159	159	157	
R-squared	0.419	0.423	0.435	0.419	0.422	0.434	0.414	0.419	0.431	0.399	0.400	0.402	0.399	0.400	0.402	0.400	0.401	0.403	
Number id	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	

Note: see Table 4

Table 7: Panel data IV estimates with country and time fixed effect. Dependent variables Inv_ent_{it} and Inv_inc_{it}

	Entrants									Incumbents								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Typology of Firm																		
TF_Lin_{it}	0.680 (0.420)	0.704* (0.421)	0.740* (0.428)							-0.008 (0.626)	-0.112 (0.560)	-0.122 (0.563)						
TF_Conv_{it}				2.495* (1.397)	2.469* (1.411)	2.604* (1.404)							0.378 (1.463)	0.114 (1.277)	0.101 (1.299)			
TF_Con_{it}							0.223 (0.183)	0.246 (0.180)	0.252 (0.190)							-0.087 (0.514)	-0.168 (0.465)	-0.179 (0.468)
Regulation																		
AR_{it-1}	0.085 (0.120)			0.086 (0.117)			0.080 (0.120)			-0.048 (0.072)			-0.047 (0.070)			-0.044 (0.073)		
$RegQ_{it-1}$		-0.919 (0.843)			-0.859 (0.838)			-0.950 (0.857)			0.275 (0.468)			0.263 (0.464)			0.288 (0.471)	
$Trans_{it-1}$			-2.236** (1.141)			-2.220* (1.137)			-2.222* (1.136)			-0.193 (0.444)			-0.180 (0.437)			-0.203 (0.447)
Competition																		
HHI_inter_{it}	1.038 (2.171)	1.106 (2.152)	1.362 (2.080)	1.280 (2.175)	1.338 (2.178)	1.605 (2.099)	0.784 (2.201)	0.835 (2.173)	1.071 (2.105)	2.815* (1.591)	2.747* (1.605)	2.734* (1.630)	2.768* (1.584)	2.702* (1.599)	2.683* (1.626)	2.842* (1.595)	2.773* (1.608)	2.765* (1.635)
HHI_intra_{it}	1.491** (0.598)	1.446** (0.598)	1.183** (0.597)	1.339** (0.618)	1.273** (0.617)	1.004 (0.626)	1.439** (0.607)	1.425** (0.607)	1.153* (0.612)	0.438 (0.356)	0.459 (0.364)	0.395 (0.358)	0.435 (0.355)	0.453 (0.364)	0.390 (0.359)	0.443 (0.357)	0.465 (0.365)	0.400 (0.359)
Income																		
$\ln GDPpc_{it}$	-4.937 (3.649)	-3.804 (3.504)	-3.325 (4.151)	-4.748 (3.660)	-3.603 (3.505)	-3.101 (4.148)	-4.994 (3.665)	-3.942 (3.503)	-3.400 (4.169)	1.199 (1.683)	0.658 (1.506)	0.352 (1.849)	1.117 (1.654)	0.564 (1.486)	0.224 (1.805)	1.224 (1.713)	0.704 (1.526)	0.418 (1.888)
Obs	154	154	152	154	154	152	154	154	152	159	159	157	159	159	157	159	159	157
R-squared	0.399	0.413	0.423	0.402	0.415	0.425	0.394	0.408	0.418	0.387	0.393	0.395	0.388	0.394	0.396	0.386	0.393	0.394
Number id	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
F-statistic	27.26	101.3	44.53	26.49	98.85	42.77	28.15	106.5	47.44	46.20	131.1	55.05	45.59	138.70	58.23	45.14	127.70	53.56

Note: see Table 4

5. Conclusions

In this study we have assessed the impact on investment behaviour in European broadband markets following major changes to the sector's regulations (including the introduction of access regulation) in 2002. We have classified firms in the European telecommunication market according to the degree of internationalization of their operations and their market knowledge, and have tested the effect of this classification and market regulation on infrastructure investment in European DSL markets.

Overall, our results suggest that regulation has not had a significant, direct impact on investment (and where an impact has been detected this has tended to be negative), and that at both levels of analysis (aggregate and separate) the firm's internationalization and market knowledge are important drivers of infrastructure investment. A separate analysis of investment by incumbent and entrant firms shows that the positive effect on investment attributable to internationalization and market knowledge is higher in the case of entrants.

The negative impact of competition on investment might indicate that the increase in competition is not accompanied by infrastructure investment, but rather by subscribers switching from incumbents to entrants. This, together with the possibility that DSL markets are currently at a stage in which the relationship between competition and investment is negative, raises questions as to the effectiveness of regulations to promote competition, and their possible long-term effects on DSL infrastructure.

In short, our results would seem to indicate that, under the current regulatory framework, entrants that choose to invest more in infrastructure are those that have most international experience in the sector. As such, overall knowledge of the telecommunication sector plays an important role. In the case of incumbents, however, investing abroad does not seem to affect their investment levels in the country of origin.

Although a number of valuable conclusions can be drawn from this study, certain shortcomings should be noted. First, given data availability, broadband infrastructure investment is not directly observable at either the firm or the country level. Second, detailed firm-level data would enable us to disentangle more clearly the respective roles being played by firms' knowledge, on the one hand, and their internationalization, on the other. Thus, subsequent studies need to incorporate disaggregated data collection, which should facilitate a better understanding of how internationalization and market knowledge in European broadband markets are related to each other.

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