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Determinants of broadband access: Is platform competition always the key variable to success?

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ABSTRACT

Previous studies have identified the rivalry among technological platforms as one of the main driving forces of broadband services penetration. This paper draws on data from the Spanish market between 2005 and 2011 to estimate the main determinants of broadband prices. Controlling for broadband tariffs features and network variables, we examine the impact of the different modes of competition on prices. We find that inter-platform competition has no significant effects over prices, while intra-platform competition is a key driver of the prices charged in the broadband market. Our analysis suggests that the impact of different types of competition on prices is critically affected by the levels of development of the broadband market achieved by the considered country.

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1. Introduction

Over the last decade, many governments have considered access to high-speed data networks – otherwise known as broadband networks[2] – a priority in the design of their economic policies.[3] The objective of these policies has been lowering prices and increasing the penetration rates of broadband services.

One of the main tools used to develop broadband services has been the use of public resources to spread the broadband networks. For example, the 2009 American Recovery and Reinvestment Act, which comprised a package of measures to stimulate the US economy, among the items budgeted were 7200 million dollars assigned to the completion of broadband networks.

However, direct government investment is not the only way to promote the technology with one of the basic tools for enhancing the penetration of broadband services being the promotion of competition among telecommunication

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[1] The views and opinions expressed herein are solely those of the author and do not necessarily reflects those of the Comisión del Mercado de las Telecomunicaciones (CMT).

[2] There are three main network types known as broadband platforms: xDSL (*Digital Subscriber Line*) Platforms: xDSL technology is based on the conversion of the copper pair telephone line into a basic high-speed digital line that can carry broadband services as well as transmit voice. The connection speed of this technology ranges from 256 Kbps to 40 Mbps. Cable modem platforms or HFC (hybrid-fiber coaxial): These hybrid networks combine optical fiber and coaxial cable. Cable platforms were deployed in many countries before the emergence of the broadband internet service as initially they were built to broadcast television frequencies. Later, in the mid-1990s, TV cable operators adapted their facilities so as to offer broadband internet services too. Cable platforms can achieve data transmission speeds in excess of 100 Mbps. Optical Fiber Platforms or FTTx: Today, this technology permits the highest data transmission speed for internet access. Fiber optic platforms can offer internet data speeds higher than 1 Gbps.

[3] Several studies have found that the expansion of broadband technology may have a significant impact on the economic growth of a country (Koutroumpis, 2009; Qiang and Rossotto, 2009; Katz and Suter,2009).

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operators. In recent years, the debate as to what constitutes the best market structure for maximizing such competition has been lively.[4]

Two types of competition have developed in most broadband markets: first, inter-platform competition, i.e., competition between two technology platforms (typically xDSL and cable platforms) in the same area; and, second, intra-platform competition, i.e., competition between operators using the same technology platform (as we shall see below, this type of competition is limited to xDSL platforms and requires regulatory intervention).

These two types of competition may have different effects on prices due to differences in the investment requirements of new operators and the role of regulation. Firstly, in the case of competition among platforms the investment requirements are critical because a new operator has to build a full network to compete in the market. In the context of intra-platform competition, the needs for investment are much lower due to the possibility to offer telecom services through the incumbent network. Secondly, the inter-platform competition performs in a deregulated environment and only according to market forces. By contrast, intra-platform competition requires an intensive regulatory intervention. Thus, the regulatory agency has to overcome multiple challenges – such as to build a real cost accounting model, to manage the existence of likely information problems or to avoid the threat of the regulatory capture – to regulate efficiently the intra-platform model. The predominant type of competition may also affect prices when considering new technologies. For example, the spread of optic fiber networks has had a different impact in cable than alternative xDLS operators. Given these differences, we can expect that the development of one mode of competition over the other may lead to different prices in the market.

Various studies (Distaso et al., 2006; Bouckaert et al., 2010) have analyzed the market in these terms and present evidence to indicate that inter-platform competition is the driving force behind the expansion of broadband services, while they have tended not to find a positive impact in the case of intra-platform competition.

This paper draws on data from the Spanish market between 2005 and 2011. The market was characterized by a low level of broadband diffusion among the population and the charging of higher prices than those applied in many European countries. Our aim here is to determine whether the results for the Spanish market verify previous empirical findings regarding competition (i.e., the dominance of inter-platform competition) and to identify the causes of the delayed development of broadband technology in this specific market. Although the study focuses on Spain, our findings should be valid for other countries with a similar development of broadband technology.

The empirical analysis reported here makes two main contributions to the literature. First, we examine the effects of different competition modes on broadband price levels. Second, we take into account all the prices of each telecom operator in the Spanish market, whereas previous studies have opted to use aggregated data at the national level. This approach allows us to examine the specific impact individual operators might have on market price performance. In contrast with previous studies, we find that intra-platform competition has been the main driver of price levels, while the impact of inter-platform competition has been insignificant.

The rest of this paper is organized as follows. Section 2 provides a brief overview of the development of broadband technology, focusing on the situation of the Spanish market. Section 3 describes different forms of competition in the broadband market and reviews the literature. Section 4 presents the empirical model and discusses the results. Section 5 closes with a summary of the main results and their implications for public policy.

2. Origin and development of broadband platforms

The need for deploying broadband networks among a high percentage of the population results from the technological revolution initiated by the expansion of the internet in the early 1990s. At the outset, most users had a narrowband access to internet based on a dial-up modem via a standard phone line. However, the exponential growth of Internet connections explains why these narrowband networks, which were nevertheless crucial for internet development, became an obstacle as users sought to access services requiring markedly higher connection speeds. The telecommunications industry responded to these new demands – both from the residential and business segments – by developing new technology platforms (i.e., xDSL, cable modem and FTTx), the so-called broadband networks.

Since the creation of these platforms, the number of broadband users has grown exponentially. An OECD study conducted in 2011 reported that up to a quarter of the population of its member countries accessed internet via broadband platforms, equivalent to 309 million broadband users. Moreover, in the last decade, broadband had experienced annual growth rates higher than 40%. The study also reported that certain European countries –including, France, the UK and Germany – all presented very similar levels of penetration and all of them above the OECD average. By contrast, a group of other countries – including, Spain, Austria, Italy and Greece – found themselves lagging some distance behind the leading group and at levels below the OECD average.

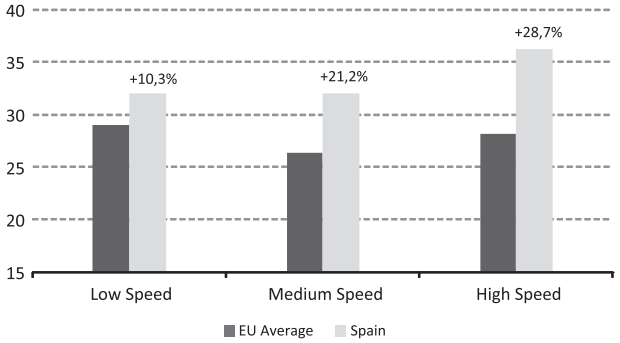
Three main groups of operators can be identified in the Spanish broadband market: (1) the incumbent who owns the public switched telephone network deployed in the country – Telefónica de España, (2) cable operators who provided their own network access nationally or regionally, and (3) alternative xDSL operators that need to access, at least partially, the incumbent operator's network to offer their broadband services. FTTx or WiMAX access technologies have only a residual presence in Spain.

Table 1 shows that, since 2004, alternative xDSL operators have increased their market significantly – almost

[4] Vogelsang (2013) claims that the different regulatory efficiency levels observed among countries is affected by a large number of heterogeneous variables, such as considerations of global competitiveness, their institutional endowment or their existing telecommunications policies.

Table 1
Development of broadband platforms in Spain.

	Coverage	Market share (%)		Variation (%)
		2004	2011	
Narrowband platforms	National	35.2	0.5	−98.5
Broadband platforms	National/Regional	64.8	99.5	53.6
Incumbent operator	National	54.9	49.2	−10.5
xDSL alternative operators	National	16.3	29.6	81.8
Unbundled local loop (%)		27.8	79.5	186.0
Bitstream (%)		72.2	20.5	−71.6
Cable operator	National	21.2	14.3	−32.6
Others cable operators	Regional	4.9	6.5	31.7
Other platforms (e.g. WiMAX)	Regional	0.4	0.5	12.9



Source: Based on information supplied by CMT

Fig. 1. Price comparison of fixed bundled tariffs, June 2010.

doubling their market presence, while Telefónica de España and national cable operators have suffered a significant loss of their market share. Particularly notable has been the evolution of the national cable operator, whose market share has fallen by 32.6% over the last 7 years.

The concept other cable operators includes a total of 36 regional operators. They have fared better than national cable operator but their whole market share – 6.5% – remains still small in national terms. The main reason for this poor outcome is that the most significant regional cable operators are located only in areas where the national cable operator has not spread its network. Therefore, they cover a small area because the national cable operator is present in the 80% of all regions where cable networks has been deployed. In fact, the national cable operator in Spain was previously built as a result of a multiple merger process of regional cable operators which finished at the end of 2004. This process entailed the disappearance of the most important regional cable operators at that time with the aim of building a competitive national cable operator. At present, the remaining regional cable operators have a modest individual share at the national level and, for this reason, the empirical regressions estimated in Section 4 does not take them into account.

Finally, Table 1 shows, as mentioned above, that virtually no internet users today access via narrowband platforms.

The international comparison of prices in the broadband market is complicated for various reasons, including: nonlinear pricing structures (that is, flat rates that include a single fixed fee for a service, regardless of usage), the great variety of commercial offers (tariffs with several connection speeds or with a monthly data allowance) and the existence of multiproduct services (i.e., bundled products combining fixed telephony, television, etc.). Yet, despite these difficulties, several organizations – including the OECD, ITU and CMT[5] – have sought to undertake an international comparison of broadband prices. The CMT, for example, publishes a half-yearly study of broadband tariffs reporting the prices of bundled offers (including broadband and fixed telephony voice services) in Spain compared to average EU prices (see Fig. 1). This offer is used as the reference price for broadband services since it is the most heavily demanded product in the Spanish market, accounting for 73.4% of all broadband contracts.

The report shows that the prices of broadband services in Spain are significantly higher than those charged on average in the EU. Likewise, the reports published by international organizations[6] present similar findings.

In short, Spain's broadband market charges higher prices than those of its EU counterparts, while the penetration rate remains low with respect to these countries. This

[5] Comisión del Mercado de las Telecomunicaciones – Spain's regulator of the telecom sector.

[6] See Van Dijk Management Consultants (2010) Broadband Internet Access Cost (BIAC). European Commission, Information Society and Media Directorate-General, Brussels.

situation may well be indicative of an abnormality in the level of competition, with the effect that Spain's market is some way from achieving optimum conditions of competition. For this reason, this study seeks to identify the impact of different forms of competition on the Spanish market and to quantify their influence on the expansion of broadband services.

3. Modes of competition in the broadband market

Inter-platform competition in the broadband internet access in Spain is focused on two technology platforms: xDSL and cable. The two platforms are completely independent of each other and there is no need to establish an interconnection to provide internet access.

Furthermore, mobile operators have recently developed the mobile broadband technology in Spain. Tariff data for these operators are not available but we do not expect that this omission has consequences on our competition analysis. Several studies such as those by Lee et al. (2011) and McDonough (2012) have analyzed the spread of mobile and fixed broadband platforms. They found that mobile broadband operators do not effectively compete with fixed broadband operators. In fact, McDonough (2012) pointed out that consumers consider the two types of broadband services as complements.

Concerning intra-platform competition, the main barrier to entry that new operators must overcome is the high level of initial investment required to deploy their own platform. Cave et al. (2001) claim that new operators would tend to start their activity by renting the incumbent's network, since their volume of investment in their own facilities is initially very low. Later, as the new operators increase their volume of investment, their independence increases with respect to the incumbent's network. Through this process, known as the investment ladder theory, new operators are encouraged to become progressively more competitive. Unlike the previous mode of competition, intra-platform competition is generated by operators using totally – or partially – the same technological platform (in this case the xDSL platform).

A number of empirical studies (Wallsten, 2006; Bouckaert et al., 2010) split intra-platform competition according to the type of access gained by the alternative operator to the incumbent's platform. Thus, they distinguish between service-based competition and facilities-based competition. The former involves operators on the lower rungs of the investment ladder that provide telecommunication services via resale or bitstream access. In this case, operators are not required to invest heavily but rather rent most of the incumbent's facilities. The latter involves operators that only rent local loop access from the incumbent, with the corresponding need to invest in their own facilities.

Once we have shown the features of these two modes of competition, we review the empirical evidence about their impact on broadband penetration rates. In their study of 46 US states, Aron and Burnstein (2003) found inter-platform competition to be a significant and positive variable for explaining the broadband penetration rate. Additionally, they claim that providing new entrants with unbundled local loop access might affect their incentives to invest in their own alternative platforms. Similarly, Garcia-Murillo and Gabel (2003) argue that there is no evidence to suggest that unbundled local loop access is associated with greater rates of broadband adoption.

Distaso et al.'s (2006) study is more similar to ours as it seeks to determine whether it is better to promote competition between xDSL platform operators (i.e., intra-platform competition) or to stimulate the entry of new platform operators thereby promoting competition in a multi-platform environment (i.e., inter-platform competition). They found the inter-platform concentration variable to be negative and statistically significant, demonstrating that this competition mode was the main driver of the diffusion of broadband services. By contrast, the intra-platform concentration variable was positive and non-significant, suggesting that the positive effect attributable to a higher degree of intra-platform competition is offset by its negative impact on inter-platform competition.

These results are supported by Bouckaert et al. (2010) who analyzed broadband penetration rates across 20 OECD countries from December 2003 to March 2008. They failed to find results that lend empirical support to the investment ladder theory; indeed, their evidence suggests that encouraging intra-platform competition may be negative for promoting investment in telecommunication networks. By contrast, they found that higher values of inter-platform competition led to higher levels of broadband adoption. Furthermore, they suggest that service-based intra-platform competition – i.e., alternative operators providing bitstream access – could undermine broadband diffusion.

In short, most empirical studies identify inter-platform competition as the key policy driver for promoting broadband adoption and facility investment. By contrast, intra-platform competition does not appear to have a significantly positive effect, and some studies even suggest it might have a negative impact on broadband development. The main aim of this current study is to assess whether inter-platform competition is the main dynamic force in promoting broadband adoption in the Spanish market.

4. Empirical analysis

In this section, we outline the data, variables and the empirical model that we develop to analyze the impact of different types of competition on prices. Specifically, we estimate an empirical model in which the dependent variable is the price of broadband services supplied by Spanish telecom operators. The explanatory variables capture different attributes of tariffs, as well as the intensity of intra- and inter-platform competition.

The data were collected from various sources. Broadband access information is taken from the quarterly and annual reports published by CMT, the Spanish telecommunications authority. Broadband access prices are taken from the webpages of the telecom operators and from the *Comparativa internacional de ofertas comerciales de banda ancha*, a biannual report of broadband access prices published by CMT (2007–2011).

The data used in this study range over 14 periods with each operator being observed in semiannual time intervals

between December 2005 and June 2011. This is the period in which data for the dependent variable and most of explanatory variables are available. Note that in previous years an intense process of mergers took place. Since then, the market has been much more stable. Overall, we work with an unbalanced panel data, containing a total of 138 observations.

Given the threefold classification of broadband access operators (the xDSL incumbent operator and owner of the PSTN; alternative xDSL operators that access, at least partially, the incumbent operator's network; and cable operators using their own access platform), in order to represent the Spanish market structure faithfully, data have been collected from the six telecom operators that operate at the national level: the incumbent (Telefónica de España), four alternative xDSL operators (Vodafone, Jazztel, Orange and Ya.com) and, finally, one cable operator (ONO).

Data are not available for all six operators for the entire period because Ya.com was absorbed by Orange in June 2007. This could create a bias in the estimation due to sample attrition in case that the remaining sample after the merger is not representative of the population sampled (Miller and Hollist, 2007). However, our data is not based on a random sample aimed to be representative of an entire population because we are dealing with all national operators that offer broadband services in Spain. Thus, our sample includes the entire population with the exception of some regional operators with a very modest share of the national market.

All variables showed below are collected at national level because the decision to enter in the market or set the broadband prices is currently made by operators at this level. Thus, xDSL operators –alternative or incumbent– set common prices for all the country Furthermore, as we pointed out above, the most important regional cable operators were merged before 2005 and since then, the resulting national cable has set national prices for all the zones with network coverage. In addition, the regulatory framework in Europe is at the national level and, consequently, European national agencies, as CMT, analyze the national market as a single market rather than the sum of local markets.

4.1. Dependent variable: prices

Most earlier studies employ the broadband penetration rate as their dependent variable. One of the main contributions of our study, however, is to estimate the impact of different modes of competition on broadband service prices, as opposed to on the broadband penetration rate. Thus, the dependent variable here is constructed from the broadband access tariffs offered by telecom operators.

Given the wide range of broadband access services available on the market (different data transfer speeds, broadband access bundled – or otherwise – with other telecommunication services, etc.) we considered it necessary to establish a selection criterion for tariffs that provides a faithful representation of the prices fixed by each operator. Thus, each broadband operator is represented by two tariffs: first, its lowest tariff (best entry) and, second, the tariff contracted by the highest number of customers. The frequency of the data is semiannual.

4.2. Competition variables

As noted above, we are primarily concerned with measuring the impact of each mode of competition – inter-platform and intra-platform – on broadband access prices in the Spanish market. Our reason for analyzing a specific geographic market is to confirm if the variables that have been shown to affect broadband penetration rates internationally – and, at the same time, broadband access prices – maintain this effect in the Spanish case. However, unlike previous studies, we use operator data as opposed to data by geographic region (i.e., by country). By doing so, we should be able to isolate the specific effects of operator characteristics that might affect broadband access prices.

However, comparing the broadband tariffs of operators in the same market (rather than between countries) means that we must find different explanatory variables to those employed to date in the literature. For example, previous studies have used the Herfindahl index as a proxy for the level of concentration/competition in a given market (Distaso et al., 2006). In our study, these variables are useless as they estimate the level of competition in a complete geographic market. Instead, therefore, we construct two variables that serve to estimate the impact of each operator on both modes of competition:

INTRA: This variable measures the level of market competition between xDSL platforms, i.e., intra-platform competition. The variable is defined as the total number of alternative xDSL operator subscriptions in relation to the total number of incumbent xDSL subscriptions. Formally:

$$\text{INTRA}(i) = \frac{q_i}{q_{inc}},$$

where qi is the number of subscriptions provided by alternative xDSL operator i and q_{inc} is the number of incumbent xDSL subscriptions.

INTER: This variable measures the level of market competition between different platforms (xDSL and Cable). The variable is defined as the total number of subscriptions of cable operator j as a share of the whole volume of xDSL subscriptions in the broadband access market. Formally:

$$\text{INTER}(j) = \frac{Y_j}{Q},$$

where $Q = \sum_i^n q_i + q_{inc}$ and Yj is the number of subscriptions provided by cable operator j.

4.3. Broadband tariff features

In order to capture the features of the broadband tariffs, we employ the following variables:

SPEED: Broadband speed (MB) offered at the prevailing broadband tariff.

BUNDLE: A variable that takes the value 0 when the tariff offers only broadband access, 1 when broadband access is bundled with a fixed phone service and 2 when the broadband service is bundled with telephony and television.
BITSTREAM: A variable that takes the value 1 when the service is provided on the basis of reselling or bitstream access to the incumbent's network, and the value 0 when the operator provides broadband services with forms of access on the final rungs of the investment ladder theory (primarily, shared and unbundling local loop). As such, this variable is used to measure the impact of service-based intra-platform competition on price levels.
CAPPED: Dichotomous variable that takes the value 1 when the tariff offers limited data allowances.

4.4. Network variables

The variable LINE contains the broadband subscriptions of each telecom operator. Telecom services belong to a network industry and as such are likely to be affected by substantial scale economies. Hence, operators with a large number of subscribers will incur lower costs due to a better exploitation of scale economies.

4.5. Summary of variables used in the empirical analysis

The following table summarizes the model's explanatory variables, the expected effect of each on the dependent variable, the justification for these expectations, and the empirical literature that supports these expected outcomes:

Although the empirical literature to date analyzes the size of demand – represented by the broadband penetration rate – and we focus on broadband prices, the results of earlier studies remain valid here as the two concepts are inversely proportional.

Note that three of the variables have not, to the best of our knowledge, been analyzed in the existing empirical literature. The evaluation of their impact on broadband access prices is possible here because we analyze the broadband services offered by telecom operators in a single geographic market, unlike the majority of previous studies that undertake international comparisons of countries using aggregated data.

Table 3 provides the descriptive statistics of the variables used in the estimation, while Table 4 shows the matrix of bivariate correlations for the variables in Table 2. Note that the LINE and concentration variables (INTRA and INTER) could be highly correlated simply because of the fact that we use the number of subscribers in calculating

Table 2
The main variables, hypotheses, arguments and references to the literature.

Variable	Hypothesis	Argument	Literature
INTRA	Positive or non-significant relationship with broadband access price	Positive effects of higher intra-platform competition are offset because this mode generates, in turn, less inter-platform competition	Garcia-Murillo and Gabel (2003), Wallsten (2006), Distaso et al. (2006) and Bouckaert et al. (2010)
INTER	Negative relationship with broadband access price	Rivalry between technological platforms is one of the most important driving forces promoting broadband competition. As a result, a higher inter-platform competition promotes the broadband penetration rate and impacts negatively on broadband access prices	Distaso et al. (2006) and Bouckaert et al. (2010)
SPEED	Positive relationship with broadband access price	Broadband data speed affects consumer willingness to pay for broadband access services	Chen and Savage (2011)
BUNDLE	Positive relationship with broadband access price	The greater the number of telecom services unbundled in the tariff, the higher the prices the subscriber should pay	Not considered in the literature
BITSTREAM	Positive relationship with broadband access price	Broadband service in geographic areas where alternative xDSL operators do not invest sufficiently in facilities is provided primarily with reseller or bitstream access and, consequently, prices are higher	Bouckaert et al. (2010)
CAPPED	Negative relationship with broadband access price	Limited data allowances negatively affect consumer willingness to pay for broadband access services	Not considered in the literature
LINE	Negative relationship with broadband access price	The likely existence of economies of scale allows operators with large numbers of subscribers to save costs	Not considered in the literature

Table 3
Descriptive statistics.

Variable	No. of observations	Mean	Standard deviation	Minimum	Maximum
PRICE	138	38.375	8.424	21.700	54.870
INTRA	138	0.071	0.076	0	0.242
INTER	138	0.036	0.080	0	0.259
SPEED	138	5352.580	6571.677	256.000	20480.000
BUNDLE	138	0.739	0.457	0.000	2.000
LINE	138	1,298,841	1,538,084	225	5,557,510
BITSTREAM	138	0.014	0.120	0	1
CAPPED	138	0.123	0.330	0	1

Table 4
Correlation matrix.

	PRICE	INTRA	INTER	SPEED	BUNDLE	LINE	BITSTREAM	CAPPED
PRICE	1							
INTRA	−0.29	1						
INTER	0.03	−0.42	1					
SPEED	0.22	−0.02	0.12	1				
BUNDLE	0.16	0.23	−0.02	0.35	1			
LINE	0.11	−0.06	0.18	0.08	−0.07	1		
BITSTREAM	0.01	0.15	−0.05	−0.04	−0.19	0.01	1	
CAPPED	−0.39	−0.20	−0.10	−0.18	−0.31	0.17	−0.04	1

Table 5
Variance decomposition of variables.

Variables	Between variation	Within variation
PRICE	0.18	0.12
INTRA	0.07	0.03
INTER	0.08	0.01
SPEED	0.74	0.94
BUNDLE	0.24	0.39
LINE	1.12	1.13
BITSTREAM	0	0.12
CAPPED	0.23	0.23

the concentration variables. A strong correlation would be indicative of a multicollinearity problem and, therefore, the regression coefficients related to the two highly correlated variables would be unreliable.

Nevertheless, the results from the matrix reject this possibility as the correlation between these variables is not considered significant. This can be explained by the fact that the variables capture different effects: on the one hand, LINE captures scale economy effects on broadband prices; on the other, INTRA and INTER seek to capture the two modes of competition in the broadband market.

Finally, we would stress the sources of variability in our data to clarify the effects that we are identifying. The dependent variable, PRICE, is based on two representative tariffs of each operator; its lowest and most popular tariffs. Several of the explanatory variables capture different features of the tariffs offered by each operator (SPEED, BUNDLE, BITSTREAM, CAPPED) while other variables capture differences between the considered operators (INTRA, INTER, LINE). Hence, the variability for the dependent variable and the explanatory variables for tariff features is at the level of each tariff offered by telecom operators, while the variability for competition and network variables is at the level of the operators. Taking this into account, Table 5 shows the variance decomposition of the variables used in the empirical analysis in two orthogonal components: the within-component and the between-component. The between variation seems to be relatively higher for prices and competition variables while the within variation is generally higher for tariff features.

4.6. Econometric specification and results

Taking the previous hypotheses into consideration, the equation to be estimated can be expressed in the following linear form:

$$\begin{aligned} LogPRICE_{i,t} = {} & const + \beta_1 INTRA_{i,t-1} + \beta_2 INTER_{i,t-1} \\ & + \beta_3 LogSPEED_{i,t} + \beta_4 BUNDLE_{i,t} \\ & + \beta_5 LogLINE_{i,t-1} + \beta_6 BITSTREAM_{i,t} \\ & + \beta_7 CAPPED_{i,t} + \varepsilon_{i,t}. \end{aligned}$$

The price of broadband access provided by operator i at moment t is a function of (a) the level of competition within xDSL platform (INTRA) at moment $t-1$, (b) the level of competition between different technology platforms providing broadband access (INTER) at moment $t-1$, (c) the broadband speed offered in the tariff (SPEED) at moment t, (d) the number of telecom services available as a bundle in the tariff (BUNDLE) at moment t, (e) the number of subscriptions held by operator i (LINE) at moment $t-1$, (f) the fact of reseller or bitstream modality being used by operator i to provide broadband services (BITSTREAM) at moment t, and (g) the limited data allowances included in the tariff (CAPPED) at moment t. The variables of PRICE, SPEED and LINE are expressed in logs, while the rest of variables are expressed in levels because they are dummy variables (BUNDLE, BITSTREAM, CAPPED) or by construction some of the observations take the value zero (INTRA, INTER).

As for the dependent variable (PRICE), the value of the price variable at moment t is unlikely to be independent of the value of that variable at moment $t-1$. For this reason a serial autocorrelation problem is likely to exist, that is, there might well be a correlation between the error terms at different points in time. In this regard, the Wooldridge test results confirm the existence of serial autocorrelation. Thus, we ran the regressions accounting for the presence of autoregressive residuals.

The price equation includes several one-period lagged explanatory variables ($t-1$) given that their full effect takes time to make an impact on the dependent variable. Intra-platform competition (INTRA), inter-platform competition (INTER) and the size of the company (LINE) do not affect broadband prices during the same period, but rather have an impact on the operators' future pricing strategies.

Regarding the competition variables, a potential bias could arise due to a simultaneous determination of those variables and prices. This potential bias could be mitigated by the use of one-period lagged values of competition variables. As it is shown in Table 5, the within variation of competition variables is much lower than that of prices. On the one hand, the lagged values of the competition

variables may not be as good instruments as they would be in a context of more variability. On the other hand, the low within variation of the competition variables could imply that the potential bias is modest. Indeed, it is likely that semiannual variations in prices do not have a strong influence on new lines managed by telecom operators because these new lines will require an important investment.

In general, two types of model are available for capturing cross-sectional heterogeneity in the context of a panel data model: fixed effects and random effects models. The models differ in terms of whether the specific effects are modeled as predetermined or as random form. In practice, this difference can be critical as the results from fixed effects and random effects models may diverge significantly.

Statistically, fixed effects can always be used with panel data as they invariably provide consistent results, but they may not be the most efficient model to run. The reason for their inefficiency is that fixed effects estimations only capture the within variation. By contrast, random effects provide a more efficient estimator because they take into account both within and between variations. Yet, the random effects estimation might not be consistent because these effects might be correlated with the explanatory variables. The Hausman test can be used to choose the most appropriate model in our context.

In addition, and as explained above, a final refinement has been made to the model to correct for serial correlation. Thus, the first and second columns in Table 6 display the estimates for the fixed effects and random effects specifications with the inclusion of a first-order autoregressive random disturbance term. Finally, for the sake of completeness, we estimate the ordinary least squares (OLS) pooled model with the serial correlation removed using the Prais–Winsten method.

Under the null hypothesis of zero correlation between the error term and the regressors, the results of the Hausman test indicate that the null hypothesis of orthogonality is rejected. As a result, the panel data model with fixed effects is preferred to that with random effects. Therefore, we focus the rest of our discussion on the estimates obtained from the panel data model with fixed effects, but note that all the estimated models produced fairly similar results. The estimation based on fixed effects (FE) gave an R^2 of 0.4591, which confirms that the proposed model provides a satisfactory fit of the explanatory power. The result of the Baltagi–Wu test supports the adjustments carried out in accordance with the Wooldridge test results and also confirms that the problem of autocorrelation has been successfully corrected.

Our results for the two variables measuring the degree of market competition show that each mode of competition has a different impact on broadband access prices. Hence, while competition between xDSL platforms (INTRA) has a negative and significant effect on the price level in three of the models estimated, competition between different technological platforms (INTER) is not significant in any case. In other words, intra-platform competition is the key variable to understand the evolution in broadband prices in the Spanish market.

As for the variables used to define the characteristics of the broadband tariffs, all are found to have a significant impact on the dependent variable with the exception of the dichotomous variable used to specify how many services are bundled in the tariff (BUNDLE). Hence, the BUNDLE variable is insignificant because operators tend to include

Table 6
Results for broadband prices in the Spanish market (dependent variable: *log*PRICE).

	Fixed effects AR(1)	Random effects AR(1)	Pooled OLS AR(1)
INTRA	−2.093876***	−0.6047259*	−0.7925918**
	(0.5892367)	(0.374151)	(0.418387)
INTER	1.748077	0.0930224	−0.2781357
	(1.805935)	(0.4284781)	(0.380742)
*log*SPEED	0.0339936**	0.0223975*	0.0302341**
	(0.0164309)	(0.0132035)	(0.0156207)
BUNDLE	0.0217309	0.0303285	0.0324847
	(0.0284938)	(0.0247976)	(0.0229636)
*log*LINE	0.2882073***	−0.0168363	0.0040782
	(0.0386816)	(0.0113629)	(0.01868)
BITSTREAM	0.1945929***	0.1544576**	0.1278966*
	(0.0749071)	(0.0726255)	(0.0802769)
CAPPED	−0.090846*	−0.202256***	−0.2284793***
	(0.0537335)	(0.0446619)	(0.0493321)
Const	−0.5469296**	3.704808***	3.405026***
	(0.2807027)	(0.1413816)	(0.2418176)
N	126	126	138
R^2	0.4591	0.2317	0.9568
Hausman Test (RE vs. FE)		79.42***	
Baltagi–Wu Test	1.3975	1.3975	

* Statistical significance at 10%.
** Statistical significance at 5%.
*** Statistical significance at 1%.

fixed phone services in broadband tariffs without any additional price increase.

The broadband speed variable (SPEED) has a significant and positive effect on broadband prices. Thus, the faster the broadband speed subscribers contract, the more expensive are the tariffs they pay. This result is largely in line with previous studies which studied the effect of this variable (Chen and Savage, 2011).

The dummy variable which reveals whether the service is provided by reseller or bitstream access (BITSTREAM) is significant and positive, i.e. the offers provided by this modality of access are more highly priced because the tariffs are offered in places where alternative operators have yet to invest sufficiently in network facilities. This result suggests that service-based intra-platform competition would not help to reduce broadband prices.

The limited data allowances variable (CAPPED) is significant and negative as such tariffs target subscribers with lower data usage. Consequently, consumers that accept this limitation benefit from discounted prices.

The size of each operator in terms of their respective number of subscribers (LINE) is shown to be significant and positive. This result therefore rejects the hypothesis that larger operators set lower prices thanks to the existence of scale economies.

Importantly, the estimated results reported here differ from those reported previously. First, our results suggest that the degree of competition within xDSL platform (INTRA) is critical in explaining the price level of broadband access services in the Spanish market. By contrast, previous studies, including Distaso et al. (2006) and Bouckaert et al. (2010), report that this variable has an insignificant or even negative impact on the market. Second, the aforementioned studies identify inter-platform competition as the driving force in the promotion of broadband adoption. This result runs contrary to the obtained here, given that the variable measuring this form of competition (INTER) is not significant.

Given these results, we infer that broadband prices in countries such as Spain, characterized as they are by a lower rate of development of their broadband markets, may respond differently to the various modes of competition. Indeed, we have observed differences between countries with regard to the diffusion of their cable platforms: even though all cable operators have had to invest in order to provide a broadband service, the initial investment required to start this service was not similar in all countries. The reason lies in the fact that, before expanding their broadband services, several countries built a cable network dedicated to broadcasting audiovisual content, whereas in other countries the presence of cable networks was only residual as audiovisual content was broadcast by alternative networks (for example, in the case of Spain, this service was provided by radio waves). Thus, the supply of cable broadband services in this latter group of countries meant their having to start from scratch the construction of a new network. Consequently, the investment required in this group of countries was much higher than that in countries where a cable network with national coverage already existed.

This high level of initial investment may have weakened the competitiveness of the new cable operators with respect to those that had been supplying broadcasting services for years in other countries. The competitive weakness of the cable networks in these countries would seem to have ensured that it was the intra-platform competition that became the real driving force in the diffusion of broadband services.

In short, the theoretically positive effects of the emergence of a new broadband platform appear not solely to be determined by its mere creation, but are also influenced by other circumstances that might even undermine the potential benefits.

5. Conclusions

This paper has analyzed the main variables that account for the evolution of broadband technology and a set of related factors in the Spanish market. The literature tends to identify inter-platform competition, i.e., the competition that exists between platforms based on different technologies, as one of the main factors driving the international expansion of broadband services. By contrast, intra-platform competition, i.e., the competition generated from regulating access by alternative operators to the incumbent operator's platform, has had a much weaker impact on the development of the broadband market, with some studies concluding that it can even have a detrimental impact on its expansion.

Our analysis, however, points to the fact that these earlier findings are not necessarily valid for all countries, an example being the Spanish market. As outlined in this paper, the diffusion of broadband access in Spain shows a delay with respect to the average rates achieved in other European countries in terms both of penetration rates and of prices. Our results for the Spanish case are diametrically opposed to those reported in most studies in the literature; to the effect that the intra-platform competition has been the main driving force for the expansion of broadband access in Spain, whereas the inter-platform competition appears to have had no impact on its development.

This result suggests that the Spanish market has benefited from potentially positive effects in line with predictions made in the framework of the investment ladder theory. In other words, the regulation of access to the incumbent's platform for alternative operators has emerged as a key variable in promoting broadband adoption. By contrast, the positive effects attributed to the competition between different technologies have not been recorded in the case of the Spanish market. It is our belief that external variables that could affect the potential platform and, therefore, inter-platform competition, must be taken into account. The presence in some countries of cable TV platforms before the emergence of broadband services would seem to be a basic element in determining the competitiveness of this technological platform.

In short, policymakers seeking to place their countries at the forefront of telecommunication technology need to encourage broadband uptake. This goal, however, can only be achieved by increasing the competitive pressure on the

pricing of such services. In order to fulfill these objectives, the promotion of tools that can ensure that the market will benefit from inter-platform competition seems essential. Failure to do so might mean that external variables related to the specific characteristics of the national markets can neutralize these potentially positive effects. Today, this question is acquiring even greater importance, at a time when new technology platforms based on optic fiber are set to generate major economic benefits.

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