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Broadband prices in the European Union: competition and commercial strategies[#]

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Abstract

This paper analyses the determinants of broadband Internet access prices in a group of 15 EU countries between 2008 and 2011. Using a rich panel dataset of broadband plans, we show the positive effect of downstream speed on prices, and report that cable and fibre-to-the-home technologies are available at lower prices per Mbps than xDSL technology. Operators' marketing strategies are also analysed as we show how much prices rise when the broadband service is offered in a bundle with voice telephony and/or television, and how much they fall when download volume caps are included. The most insightful results of this study are provided by a group of metrics that represent the situation of competition and entry patterns in the broadband market. We show that consumer segmentation positively affects prices. On the other hand, broadband prices are higher in countries where entrants make greater use of bitstream access and lower when they use more intensively direct access (local loop unbundling). However, we do not find a significant effect of inter-platform competition on prices.

Keywords: Telecommunications, Broadband prices, European Union, Competition, Regulation

JEL: L51, L86, L96.

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1. Introduction

Over the last decade, millions of people in the European Union have installed broadband in their households[1], enabling them to download information and use sophisticated digital services[2]. Broadband Internet access is an essential component of inclusiveness in the 21st century, and households without access to this service are in risk of becoming marginalized from society and economic opportunity. Several papers have analyzed the impact that technological change and regulation have had in the expansion of Internet. However, little attention has been given to how telecommunication operators have modified their business strategies to respond to market evolution and competition. A detailed analysis of the managerial behaviour of operators is essential if we are to understand the significant price and quality differences that have emerged across Europe.

This paper examines the factors determining fixed broadband Internet prices in 15 EU countries between 2008 and 2011[3]. We employ a rich data set that contains both the commercial and technical characteristics of 2,204 plans offered by incumbent and entrant operators. By using an instrumental variable approach we estimate a pricing equation using three types of variable: (1) the technical characteristics of the plans; (2) the operators' commercial strategies; and (3) the patterns of competition in the country. To the best of our knowledge, this is the first paper to use information at the level of the individual firm's commercial plans to examine the determinants of prices in the EU.

Our study shows how operators adjust their prices to the technological characteristics of the plans. First, we show that downstream speed has a positive and significant non-linear impact on price: a 10 Mbps increase in the downstream speed increases the price by around 5%. And second, after controlling for downstream speed, we find that cable or fibre-to-the-home (FTTH) broadband plans are cheaper than xDSL offers. This result is important for orienting regulatory policy in the sector, as it questions the interest that operators might have for deploying Next Generation Access Networks (NGAs).

This paper also shows the importance of the operators' commercial practices. Thus while flat rate plans are more expensive than metered plans (which are limited in volume), plans that offer a broadband service bundled with voice telephony and/or television are considerably higher in price, especially in the case of triple packages. Given the importance of such bundling practices in many European markets today, we also analyse the main determinants of this commercial practice.

Finally, we examine how levels of competition and regulation affect operators' pricing decisions. We show that incumbents set prices that are often significantly higher than those of their competitors, which might be a consequence of such factors as their wider

[1] The European Commission (2008) defines broadband internet access as "an access assuring an always-on service with speeds in excess of 144 kbps. This speed is measured in download terms."

[2] During the nineties, broadband was delivered over cable and telephone lines. In the years that followed, these technologies where upgraded and some operators began to deploy fibre to the home delivery, which supports higher bandwidth (Greenstein and McDevitt, 2011a and 2011b).

[3] In spite of their growing relevance, broadband mobile services are not included in this analysis. Note that the commercial characteristics of mobile offers differ markedly from those of fixed broadband Internet access. For example, download speed is significantly slower in the case of mobile offers (although new wireless technologies such as LTE can provide speeds similar to fixed broadband)

coverage, reputation, or the existence of consumer switching costs. In contrast, the degree of price dispersion and the overall number of plans offered in any given country have a positive effect on prices. This result illustrates that market segmentation and consumer confusion in the face of various marketing plans allow operators to increase their prices.

A further contribution of this paper is to identify the effects of access regulation. We find that prices are higher in countries where entrants make much greater use of bitstream access, and lower in markets where they rely more heavily on direct access (local loop unbundling, LLU). Despite this, we observe no significant effect on prices when entrants upgrade their own networks, nor do we find any effect of inter-platform competition between xDSL, cable and FTTx. These results might be interpreted as a consequence of the application of a "ladder of investment" approach (LOI),[4] whereby in order to promote sector competition regulators need initially to facilitate the access of new entrants to the incumbent's network so as to guarantee service-based competition, and subsequently, once these entrants have acquired experience and reputation they need to provide incentives to entrants to invest in their own infrastructure. In this way, the long-term benefits of facility-based competition can be reconciled with short-term price reductions.

The rest of the paper is organised as follows. Section 2 reviews the economic literature, so as to highlight the contributions of this paper, and it describes the European broadband market. Section 3 outlines our estimation strategy. Section 4 describes the data set. Section 5 presents the empirical strategy and results and Section 6 discusses the main contributions. Finally, Section 7 concludes.

2. Literature review and European broadband market

2.1 Broadband access: the literature

The initial empirical literature on broadband Internet access focussed on the determinants of its penetration. For example, Distaso, Lupi and Manenti (2006) reported the impact of inter-platform competition on broadband penetration in 14 European countries from 2000 to 2004. They found that while inter-platform competition had a positive effect on penetration, intra-platform did not play an important role. Other studies, including Höffler (2007), highlighted the inefficiencies created by the duplication of existing platforms.

More recent papers have analysed the impact of access policies on the investment decisions of firms and on the diffusion of the service.[5] Grajek and Röller (2012) examine the effects of access regulation on incentives for investment in 20 countries in the period 1997-2006. They report that regulation discourages the investment of incumbents and individual entrants, and suggest that the European regulatory framework fails to provide incentives for facility-based competition. They also examine the regulators' response to infrastructure investments, concluding that access regulation is not affected by entrants' investments, but rather that the intensity of regulation reflects the incumbent's investments. Bouckaert, Van

[4]The "ladder of investment" regulatory model was first identified by Cave (2006). See Cambini and Jiang (2009) for an extensive review of the literature on this topic and Bourreau et al. (2010) for a critical analysis of this regulatory approach.

[5] A detailed review of the theoretical literature on access charges in telecommunications can be found in Laffont and Tirole (2000), Arsmtrong (2002), and Vogelsang (2006).

Dijk and Verboven (2010) investigate the influence of competition on broadband penetration in a sample of 20 OECD countries. They consider three entry patterns adopted by broadband operators: (1) inter-platform competition, where the incumbent xDSL operators compete with infrastructure-based operators (e.g. cable and FTTH); (2) facility-based intra-platform competition, in which entrants lease some unbundled local loop elements, but have to invest in their own equipment and facilities (e.g. LLU and share lines); and (3) service-based intra-platform competition, where entrants resell the incumbent's services (bitstream access/resale). According to these authors, only infrastructure-based competition increases the penetration of the service, while the other types have little effect.

Few papers have undertaken specific country studies. Pereira and Ribeiro (2010) examine the competition between xDSL and cable operators in Portugal. They find that inter-platform competition (mainly between xDSL and cable) increases the diffusion of Internet thanks to both the higher coverage of broadband access and the existence of lower prices. More recently, Nardotto, Valletti and Verboven (2012) have analysed the impact of unbundling on broadband penetration in the UK during the period 2005-2010 using micro level information. They find that LLU had little or no effect on broadband penetration, although it increased the quality of the service in terms of average broadband speed. On the other hand, they show that inter-platform competition from cable increased local broadband penetration.

Many of the above results contrast with those reported by Gruber and Koutroumpis (2013) who, when drawing on data from 167 countries between 2000 and 2010, find that inter-platform competition is an impediment to broadband adoption. They conclude that markets that focus specifically on one type of technology typically present a more rapid adoption process than that experienced in multi-technology markets. They suggest that this is because the latter type of competition requires the duplication of networks, which increases costs and, ultimately, prices. In contrast, full retail unbundling increases the diffusion of the service.

While there have been several studies of broadband penetration in recent years, the determinants of the prices of the service have received much less attention.[6] Explanations for this include the absence of consistent data, and the fact that broadband services are highly varied and typically offered jointly with voice telephony and television. An exception is provided by Wallsten and Riso (2010), who examine a data set comprising 30 OECD countries between 2007 and 2009. They find that downstream speed had a positive effect on prices, that broadband plans with bit caps were on average offered at lower prices than unlimited plans with contracts, and that plans with contracts were typically less expensive than those without. Their paper has several points in common with our study, but they do not examine the impact of access regulation on retail prices.

Greenstein and McDevitt (2011) also analyse the economic value created by the diffusion of broadband Internet provided via xDSL and cable in the United States. They do not have direct information on prices, but create a price index that allows them to adjust the price to the progressive improvement in service quality. Taking this into account, they show that broadband prices in the US fell slightly during the period 2004-2009. This is a very

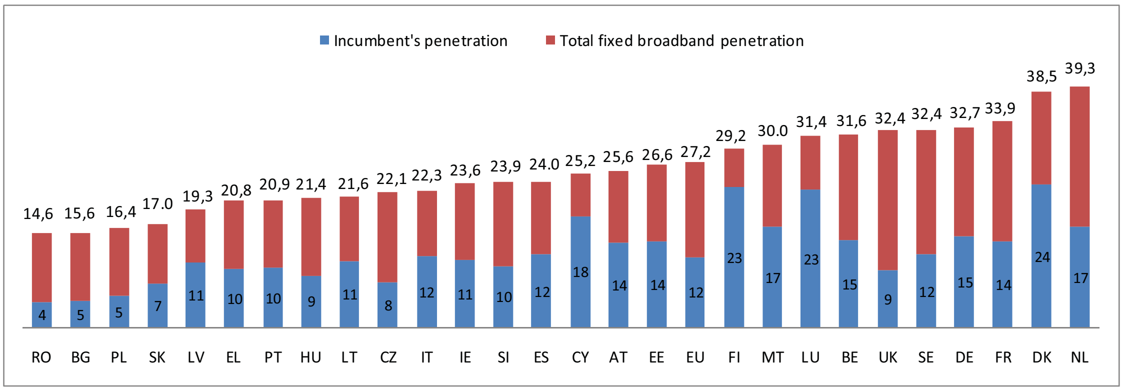
[6] Galperin (2012) describes the evolution of broadband prices in Latin America.

different evolution to that of the prices of electronic products, including laptops and printers, where the quality-adjusted price falls have been significant.

2.2 The European broadband market

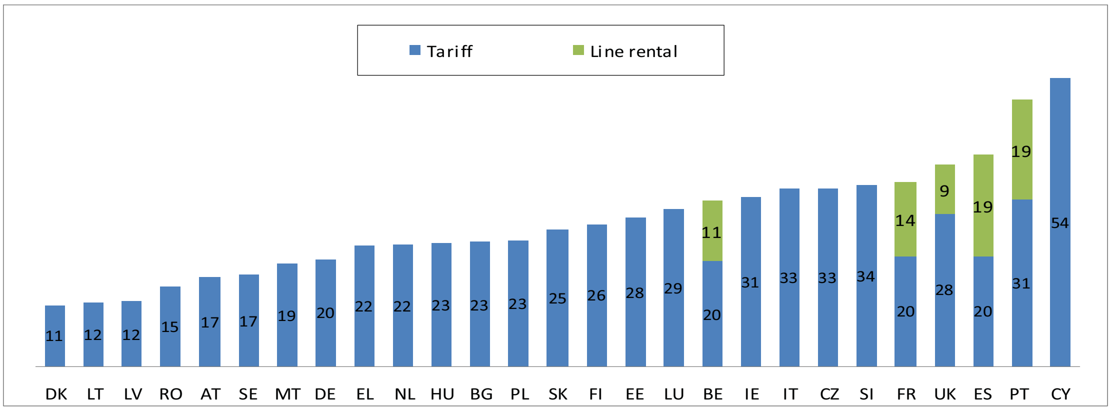
In July 2011, the average penetration level of fixed broadband Internet access in the European Union was 27.2%[7]. However, there were significant differences across member States. For example, while the penetration levels in Netherlands, Denmark and France were 39.3, 38.5 and 33.9%, respectively, in Romania, Bulgaria and Poland they were 14.6, 15.6 and 16.4%, respectively (Figure 1).[8]

Figure 1: Fixed broadband penetration and incumbent's penetration in 2011 (%)



Source: European Commission (2011a).

Figure 2: Fixed broadband prices in 2011 (€ PPP)
Least expensive offer (all ISPs): Basket 4096 kbps-8192 kbps, 5GB or 20 hours/month



Source: European Commission (2011b).

[7] The penetration of large screen mobile broadband subscriptions (using dedicated data cards or USB modems) was 7.5 % in July 2011.
[8] See European Commission Implementation Reports and European Commission (2011a and 2011b).

In recent years, the prices of fixed broadband Internet access have fallen significantly, which is quite remarkable if we consider that operators have significantly improved the quality of their offers. They often allow consumers to migrate at no cost to other offers providing higher download speeds. Moreover, there is a trend towards bundling complementary services, such as broadband with fixed voice and TV, and more recently with mobile telephony (voice and data). Such packages allow operators to attract new consumers (the bundle being cheaper than the sum of the single services) and, at the same time, to gain the loyalty of their subscribers.

This situation has not prevented significant price differences across European countries (Figure 2).[9] These differences can be accounted for in part by technical and commercial features, but they also reflect the level of competition in the market. Thus, while in 2011 the incumbent's market shares in Finland, Cyprus and Luxemburg were 79, 73 and 72%, respectively; in the UK, Bulgaria and Romania they were 29, 29 and 30%. Many member States have four or five alternative operators, but other markets are much more fragmented. For example, in Germany there are around 100 regional entrants, though the incumbent retains a 46% market share. The objective of our paper is to analyse how technical, commercial and regulatory factors affect prices and to understand how they determine price differences across member States.

Broadband access can be provided via several technologies. In the period we study, the most frequently employed system is xDSL followed by cable modem, but some operators use FTTH or wireless technologies such as 3G, Wimax and satellite. Around 77% of the fixed access lines in European countries use the xDSL technology, which explains why the average speed is still quite low (around 10 Mbps) and why there is more intra-platform than inter-platform competition.

Incumbent operators are usually vertically integrated (except in Sweden, the UK and Italy) and use xDSL (although some use cable, for example Portugal). Most entrants use the incumbent's network to provide their services and have to pay a regulated access fee. Cable operators have built their own infrastructure, but they also need to sign interconnection agreements with incumbent operators because of their limited national coverage.

In the EU, National Regulatory Authorities (NRAs) set interconnection prices in order to guarantee an adequate development of competition. There are two mandatory types of access. Entrants can access the incumbent's network directly (LLU) or indirectly (bitstream). At the same time, the direct access can be of three types: complete unbundling of the local loop, where entrants pay to use the incumbent's access lines without any restriction; shared LLU, where entrants use the high frequencies of the access lines to provide broadband and incumbents use the low frequencies to provide voice telephony; and, shared LLU without voice telephony (*naked ADSL*), which is similar to the previous service but voice telephony is offered over the Internet (VoIP). The main advantages of unbundling are, therefore, to allow entrants to offer a differentiated service and to develop their own commercial policy.

[9] In the EU, retail prices of broadband services are not regulated. However, national regulators periodically assess whether there is a "margin squeeze" that reduces the profitability of entrants. This might occur, for example, when the level of interconnection prices (wholesale access prices) make impossible to entrants from matching the incumbent's offers.

In the case of indirect access (bitstream), entrants can access the incumbent's network at two levels: at the ATM level (or Gig-ADSL), where there are several geographical interconnections, and at the IP level (or ADSL-IP), which is more expensive because there are fewer interconnection points.

Price regulation of all these access services is an essential instrument for promoting competition and investment. Regulated access prices determine in which part of the incumbent's network the entrants will choose to invest and influence both retail prices and service quality. In the EU, following the "ladder of investment" (LOI) regulatory model, regulators set the prices of indirect and direct access (bitstream and LLU) in order to provide incentives to entrants to invest progressively in their own equipment. In spite of this, the empirical literature is still unclear about the effectiveness of this strategy (Hazlett and Bazelon, 2005; Bourreau and Dogan, 2006; Waverman et al., 2007; Bacache et al., 2011, and Grajek and Röller, 2012). As Bourreau et al. (2010) explain, the main problem of the LOI is that once entrants obtain some profits with bitstream access, their incentives to invest may not be so high, creating a "replacement effect". Moreover, the simultaneous presence of multiple access levels can hinder incentives to access higher rungs on the investment ladder. Our paper contributes to the empirical literature on access regulation by assessing how the degree of intensity of each type of entry in a country affects retail prices.

3. Estimation strategy

This section examines the prices of broadband Internet access in 15 European countries in the period 2008-2011. After adjusting for the hedonic features of the operators' plans, we analyse the impact of several commercial strategies adopted by operators, including bundling and market segmentation. Additionally, we assess how different entry patterns (bitstream, LLU and own network) induced by access regulations affect retail prices.

We estimate a model for the prices of broadband residential plans (p_{mit}), where *m* is the offer, *i* is the country, and *t* is the time period. The explanatory variables that we use in the estimation can be grouped into three blocks: (1) technical characteristics of the service; (2) the operators' commercial strategies and (3) measures of competition and regulation in the country. We also control for the degree of penetration of the service in the country, as well as fixed country and time effects. Specifically, we estimate the following model:

$$
\begin{aligned}
p_{\text{mit}} = {} & \underbrace{a_0 + a_1 Speed_{\text{mit}} + a_2\, Speed_{\text{mit}}^2 + a_3 Technology_{\text{mit}}}_{\text{Technical characteristics}} \\
& \underbrace{+ a_4 Bundling_{\text{mit}} + a_5 VoIP_{\text{mit}} + a_6 Datacap_{\text{mit}} + a_7 Volumecap_{\text{mit}}}_{\text{Commercial characteristics}} \\
& \underbrace{+ a_8 Incumbent_{\text{mit.}} + a_9 PDispersion_{\text{it}} + a_{10} NOffers_{\text{it}} + a_{11} HHIPlat_{\text{it}} + a_{12} Bitstream_{\text{it}} + a_{13} Directaccess_{\text{it}} + a_{14} Ownnetwork_{\text{it}}}_{\text{Measures of competition and regulation}} \\
& + a_{15} Penetration_{\text{it}} + a_{16} Region_{\text{t}} + a_{17} Time_{\text{t}} + e_{mit}
\end{aligned}
$$

The prices charged by operators in each country may vary according to the quality of the service and the access technology. In our model, *Speed* is the downstream speed specified in the technical details of the operators' plans. To account for a possible non-linear relationship between price and speed, the equation also includes the square of the speed. *Technology* is the access technology used to provide the service; this might be xDSL, cable, or fibre (FTTH). We expect each technology to have a different effect on the price given that they require different levels of investment and bandwidths, and because consumers might have different "perceptions" of the quality of each technology.

The price equation also includes commercial practices that may be adopted by operators. *Bundling* refers to a broadband service provided together with voice telephony and/or television. The commercialisation of broadband with other services implies additional costs for the operators that can justify a price increase. For example, to be able to offer television services, operators must first reach agreements with TV channels and pay them a compensation. The variable *VoIP* reflects the situation where the broadband service is bundled together with voice telephony but provided over IP, which reduces the operators' costs (naked xDSL).[10]

Datacap is a dummy variable that shows if the plan includes a restriction in the user's downstream volume (consumers have to pay an extra charge when they exceed the established cap), and *Volumecap* measures the volume of data that the user can download. A priori, we expect the capped offers to be cheaper than those with unlimited downstream capacity, and also for prices to increase with the volume of the download limit.

We examine a group of variables that reflect the competition in the national markets. *Incumbent* is a dummy that identifies the different pricing policies of the incumbent and the entrants. Incumbents may have market power thanks to certain advantages of reputation or to the existence of consumer switching costs. They may also have cost advantages over their rivals. Yet, European operators may be the incumbent in one country and the entrant in another or others. Thus, the costs of incumbent operators are also related to their presence in several countries and to their bargaining power with their equipment providers.

HHIPlat is the concentration Herfindahl-Hirschman Index (HHI) in terms of technology shares. A higher *HHIPlat* would mean a high concentration of a particular technology in a given country. As discussed in Section 2, the empirical literature is ambiguous with regard to the effect of inter-platform competition on the diffusion of the service (see, for example, Bouckaert, van Dijk and Verboven, 2010 and Gruber and Koutroumpis, 2013), and its effect on prices is also unclear. Here, a factor that should be considered is that inter-platform competition allows operators to differentiate their services, which might offset price reductions due to higher competition between different platforms.

PDispersion measures the price dispersion of all the plans commercialised in the country, and *NOffers* is the number of plans offered by the incumbent. Both variables are proxies of the degree of price discrimination in the market. Incumbents can offer a large number of plans to better respond to competitors that target specific groups of consumers, but they can also segment the market if they have market power.

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[10] Our model does not consider if the consumer can subscribe separately to each service ("menu à la carte") or if the client has no option other than to contract the bundle (so-called *Tying*). The reason is that it is difficult to gather this information and also the problem of multicollinearity between the variables *Tying* and *Bundling*.

Finally, a principal objective of this study is to determine how different types of entry in the country (bitstream, LLU and the development of entrants' own networks) affect the operators' pricing strategies. *Bitstream*, *Directaccess*, and *Ownnetwork* are explanatory variables that reflect the relative importance of these entry patterns. Notice that important distinctions can be drawn between *Ownnetwork* and *HHIPlat*. Thus, while the former identifies an entrant that bypasses the incumbent's network (implying the duplication of networks), the latter reflects the presence of different technologies in the country, though not necessarily the duplication of networks, i.e., the market might be geographically segmented by technologies[11]. The inclusion of these variables in the pricing equation is useful to analyse the effects of access regulation, although there are other important aspects that also determine the entry strategy of operators, including the investment that is needed to deploy the equipment, the operators' perceptions of consumer willingness to pay for high-quality services, or the regulatory institutions in the country.

Unfortunately, our data set does not provide any information about the number of clients that subscribed to each of the commercial plans. Yet, the variable *Penetration* offers details of the number of subscribers in each country for five different speed ranges. In the presence of economies of scale, we expect operators to set lower prices as they have a larger penetration and more subscribers to their plans. However, this effect may be moderated when the increase in penetration is achieved as a result of extending service coverage to high cost/low density regions.

4. The data

We use a panel data of residential retail broadband offers in 15 European member States for the period December 2008 to June 2011. The countries analysed represent more than 80% of the total broadband access lines in the EU. On average the data set contains around 550 offers per year and an overall total of 2,204 observations (Table 1). The sample includes the tariffs of operators whose accumulative subscribers represent over 90% of the broadband market in each country. Most of our data are drawn from Quantum-Web Ltd. Data for the countries' penetration rates and socio-economic variables are provided by the European Commission, Eurostat and UNESCO.

Information concerning the technical and commercial characteristics of each offer is collected primarily from the operators' web sites by Quantum-Web. It should be stressed that the prices offered on these sites might differ in some cases from those offered via other sales channels (e.g. operators' retail shops). Likewise, operators may negotiate discounts with consumers when the latter have received better offers from rivals or when they want to attract new subscribers. In the case of the technical characteristics, note that the download speed advertised might not be uniform across all households.

The price of the offer used as the dependent variable is the monthly payment in euros advertised by the operator and adjusted by each country's purchasing power parity (PPP). Some offers include the monthly line rental fee, which is commonly associated with voice telephony. This is typically the case for xDSL, unless the voice service is provided via VoIP, but not in the cases of cable and FTTH technologies. To account for this situation,

[11] An example of market segmentation by technology is Belgium where the broadband lines in Flanders are usually cable, while in Wallonia there is a more intensive use of xDSL.

we consider the price of each offer as being the sum of the access fee (the line rental) and the broadband service tariff[12]. Note that in some cases the offer establishes limits to the downstream volume, which means that consumers have to pay an additional charge once this limit has been exceeded. Our price does not include these additional payments, although the variables *Datacap* and *Volumecap* control for this situation.

We use two hedonic variables to estimate the price. *Speed* is the quality of the service advertised on the operators' web pages and is measured in Mbps. The minimum speed in our sample is 0.128 kbps and the maximum is 500 Mbps. However, a significant number of plans offer a quality between 10 and 30 Mbps (Table 2).

Table 1: Descriptive statistics. Period 2008-2011

Variable	Observations	Mean	Standard Deviation	Minimum Values	Maximum Values
Price (euros)	2204	35.8	14.8	7.1	138.5
Price Single broadband (euros)	909	30.3	12.3	7.3	82.5
Price Broadband and voice (euros)	699	35.9	12.9	7.1	107.7
Price Broadband and TV (euros)	116	39.7	12.9	15.1	72.2
PriceBroadband, voice and TV (euros)	480	45.2	16.8	13.8	138.5
Price for Metered offers (euros)	410	36.7	14.7	7.1	79.8
Volume cap (Gb)	410	64.0	135.9	0.4	1000.0
Speed (Mbps)	2204	23.8	32.6	0.1	500.0
HHI inter-platform	2204	63.6	17.2	38.0	100.0
Bitstream access Index	2204	4.2	8.3	0.0	48.27
Direct access Index	2204	32.1	44.7	0.2	171.7
Own network access Index	2204	52.1	76.5	0.0	405.9

Source: Quantum Web-Ltd

The variable *Technology* reflects the type of access used to provide the service; this can be xDSL, cable or FTTH. Taking this into account, the variable takes a value of 1, 2 or 3, respectively. It should be stressed that the download speed is related to the technology used in providing the service. Thus, xDSL cannot offer more than 30 Mbps, with the sole exception of VDSL which can reach 50 Mbps. By contrast, cable supports speeds of up to 100 Mbps (DOCSIS3.0) and FTTH can attain download speeds of 1 Gbps. Also, an operator's bundling strategy depends on its technology. xDSL is usually bundled with voice telephony, but not with television because good quality cannot be guaranteed. Cable and FTTH, on the other hand, are often provided together with television.

Broadband access can be bundled with other services and commercialised at a single price. To identify the incremental price that this implies, the variable *Bundle* takes values of 1, 2, 3 or 4, depending on whether broadband access is offered individually or bundled with fixed voice telephony, TV, or with both[13].

[12] Prices do not include any other costs, such as the price of routers or the installation fee.

[13] In contrast with Wallsten and Riso (2010), we have no information about the number of channels in triple play packages.

Datacap is a dummy variable that takes a value of 1 when the offer includes a limit to the downstream volume, and 0 otherwise. The variable *Volumecap* measures the limit to the download capacity (rated in GB) in offers with a downstream volume. Consumers usually pay an extra charge if they exceed the downstream limit, but as explained above we do not consider these charges in our analysis[14].

Competition and regulation are essential aspects for understanding the operators' pricing policy. Our dataset provides information about the number of lines per operator in each country, classified according to the technology used and the type of access (bitstream, direct access, and own network). We use this information to construct concentration indexes that measure the entry patterns in each country. Bitstream access concentration (*Bitstream*) is defined as the square of the entrants' bitstream market share (GigADSL o IP-ADSL) in the country divided by the square of the incumbent's market share. Direct access concentration (*Directaccess*) is the square of the entrants' direct access market share divided by the square of the incumbent's market share. Own network concentration (*Ownnetwork*) is the sum of the squares of the entrants' market share of own lines divided by the square of the incumbent's market share. As such, these indexes show the relevance of alternative entry patterns in relation to the incumbent's market share. In most European countries, broadband services are in the main provided by legacy communication infrastructure, where the incumbent operator maintains significant market power. Taking this into account, we analyse how the intensity of different entry patterns with respect to the incumbent's position affects prices, and we also examine the response of prices to each entry pattern.

A further instrument for measuring the competition level is the concentration of technological platforms. To capture this, *HHIPlat* is the Herfindahl-Hirschman Index for each country, which is estimated by adding the sum of the squares of market shares by technology (xDSL, cable, FTTx).

PDispersion and *NOffers* can be interpreted as proxies of the degree of price discrimination, and are calculated with the information obtained by Quantum-Web from the operators' web sites. *PDispersion* is the standard deviation of broadband prices, and is calculated as the square root of the variance in prices in each country for each year. *NOffers* is the number of offers commercialised by the incumbent in each country and in each year. We might alternatively have used the total number of offers commercialised in the country, but have opted not to do so as we are unsure that our data set contains information about all existing entrants.

Penetration is defined as the number of broadband subscriptions per 100 inhabitants in a country. For the level of penetration we use EU information for five downstream speed ranges: (1) below 2 Mbps, (2) 2-9.99 Mbps, (3) 10-29.99 Mbps, (4) 30-99.99 Mbps, and (5) above 100 Mbps (ultrafast speed). The last two ranges are usually provided by cable or FTTx, although the VDSL can also support speeds up to 50 Mbps.

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[14]Metered broadband plans charge for an additional capacity (GB) and some offers are time metered. The extra costs (the so-called overage charges) are paid per GB or per a discrete number of extra GB, and less frequently the plan charges per day, hour or minute above the cap limit. In some cases, no overage charges are made and the broadband plans experience a sharp reduction in download speed once the cap has been exceeded (bandwidth throttling).

The pricing equation also includes the dummy variable *Region* to account for the unobserved heterogeneity in each market. The EU-15 countries have been clustered into three groups owing to very high multicollinearity between country dummies. We have tested that there are no significant differences in prices within each group after controlling for the rest of the variables. In this way we avoid problems of multicollinearity and the loss of degrees of freedom in the regression. The *Region* variable takes a value of 1 for Spain, Belgium, Greece, Luxembourg and Portugal; 2 for Austria, Denmark, Netherlands, Finland and Ireland; and 3 for France, Germany, Italy, Sweden and United Kingdom. Finally, *Time,* is a dummy fixed effect for each year.

For illustrative purposes, Table 2 shows some of the most relevant characteristics of the broadband plans for each country in 2011. The table highlights the differences across countries in terms of price and download speed. Direct observation of these statistics suggests that average prices might be affected by the speeds, but also by other factors such as bundling or volume caps. The econometric analysis conducted in the next section seeks to identify the main factors determining the operator prices and sheds some light on the differences across countries.

Table 2: Residential Broadband Plans. Characteristics by Country in 2011

	Observa-tions	Number of Operators	Average Price (euros)	Average Download Speed	Bundling (% bundled plans)	Metered Offers (%)	Average Volume Cap (Gb)	Bitstream market share (%)	ULL market share (%)	Own Network market share (%)
Austria	71	7	39.6	29.9	58%	20%	58.4	2%	13%	25%
Belgium	32	5	42.6	20.2	34%	56%	25.5	5%	4%	37%
Denmark	12	3	25.9	27.3	58%	42%	208.3	7%	10%	22%
Finland	26	4	26.4	27.5	0%	4%	0.1	3%	2%	63%
France	46	5	34.3	52.9	93%	-	-	8%	43%	7%
Germany	55	10	26.6	28.2	65%	2%	1.8	7%	36%	12%
Greece	33	5	40.3	18.6	61%	-	-	2%	56%	0%
Ireland	38	4	38.1	17.3	55%	63%	29.2	20%	5%	26%
Italy	26	6	29.1	10.6	42%	15%	0.1	14%	30%	4%
Luxembourg	19	3	36.3	18.6	32%	16%	1.4	0%	11%	0%
Netherlands	60	9	39.3	29.6	53%	-	-	2%	13%	40%
Portugal	33	5	53.1	69.4	88%	39%	18.2	2%	9%	40%
Spain	47	7	56.9	20.9	89%	2%	0.0	6%	24%	18%
Sweden	53	5	28.7	36.9	32%	-	-	4%	14%	39%
UK	39	6	30.7	23.4	67%	31%	7.0	11%	38%	21%

Source: Quantum-Web Ltd

5. Estimation and results

This section presents an econometric multivariate analysis of the factors influencing broadband Internet access prices. We estimate the pricing equation using three estimation procedures: ordinary least squares (OLS), two-stage least squares (2SLS-IV) and three-stage least squares estimations (3SLS-IV)[15]. We believe that our OLS estimates may suffer from an endogeneity problem. Indeed, economic theory suggests that in countries where prices are low, penetration levels might be higher. In such a case, the OLS coefficients of

[15] We have discarded the use of a fixed effects model because of the severe attrition or identification of our broadband plans (offers change over time or are substituted by others) and the little variance in our observations during the period considered (with information covering four years). We have also ruled out the use of a random effects model because the unobserved heterogeneity (the firm or country unobserved characteristics) will be correlated with the explanatory variables in the pricing equation.

penetration are likely to be biased downwards, and so we would erroneously conclude that penetration has a smaller effect on price than it actually has. Taking this into account, we use instrumental variable techniques and we examine the possibility of using different socio-economic variables as instruments for *Penetration*: *GDPpc* is the gross domestic product per capita; *Density* is the number of inhabitants in the country divided by its area in square kilometres; *Education* is the percentage of population with upper-secondary education; and *Unemployment* is the unemployment rate in each country. Data for *GDP*, *Density and Unemployment* have been obtained from Eurostat, and *Education* from the UNESCO data base.

We expect *GDPpc*, *Density* and *Education* to have a positive effect on the adoption of internet and *Unemployment* to have a negative effect. We expect *GDPpc* to affect Internet penetration but not broadband prices. In addition, both *Price* and *GDPpc* are adjusted by each country's PPP so as to account for differences in the cost of living across EU member States. *Density* should reduce operator's costs for network deployment and, hence, should have a positive effect on coverage. However, the effect of *Density* on price is unclear, since while *Density* is defined at a national level, population density can vary greatly across regions, which might affect the pricing decisions of incumbents and entrants. As for *Education,* we expect the more highly educated to be more likely to contract Internet, but the level of education should have no impact on the operators' price setting decisions.

Likewise, it should be noted that the concentration indexes (*HHIPlat, Bitstream, Directaccess and Ownnetwork*) might also be affected by an endogeneity problem since the entrants' entry decisions could be determined simultaneously with prices. Yet, a high index value might also reflect the presence of efficient entrants that are able to provide the service at a low price, or who are perceived by consumers as being better. To account for this situation, our model includes country fixed effects to represent the unobserved characteristics that influence the efficiency of operators and, eventually, the level of retail prices. Examples of these unobserved effects include investments, administrative constraints, and state aid plans that are specific to each country.

Table 3 reports the OLS and 2SLS/3SLS-IV estimates of the pricing equation. The first three columns present the OLS results. Specification 1 considers the technical characteristics of the offers and the commercial strategies of the operators. Specification 2 includes the competition and regulatory variables and specification 3 adds *Penetration.* Finally, specifications 4 and 5 show the results of the 2SLS and 3SLS estimations using as instruments the socio-economic variables *GDPpc*, *Density* and *Education.* Since the dependent variable *price* is included in logs, *Penetration* is interpreted as a semi-elasticity. All specifications include the *Time* and *Regional Effect* dummy variables.

Table 3: Estimation Results: All Broadband plans. OLS; 2SLS/3SLS-IV

Dependent variable	**Specification 1**	**Specification 2**	**Specification 3**	**Specification 4**	**Specification 5**
Log Price (*price*)	**OLS**	**OLS**	**OLS**	**2SLS-IV**	**3SLS-IV**
Independent variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Penetration			**-0.0057*** (0.00312)	**-0.017**** (0.00723)	**-0.019**** (0.00723)
Speed	**0.0065***** (0.00146)	**0.0069***** (0.0014)	**0.006***** (0.00159)	**0.0042***** (0.00185)	**0.0047***** (0.00107)
Speed²	**-1.1e-05**** (0.000004	**-1.1e-05**** (0.000004	**-9.2e-06*** (0.000004)	**-5.4e-06*** (0.000005)	**-1.5e-05*** (0.000003)
Technology dummy (reference xDSL)					
Cable	**-0.092*** (0.05150)	**-0.11**** (0.04710)	**-0.11**** (0.04577)	**-0.15***** (0.03449)	**-0.10**** (0.02133)
FTTx	**-0.11**** (0.0582)	**-0.11**** (0.05026)	**-0.12**** (0.05135)	**-0.14**** (0.04405)	**-0.11**** (0.02515)
Metered offer (Data cap)	**-0.098** (0.05860)	**-0.17***** (0.05739)	**-0.18***** (0.05816)	**-0.18***** (0.05773)	**-0.16***** (0.01878)
Volume cap	**0.00043** (0.00030)	**0.00049*** (0.00023)	**0.00049**** (0.00022)	**0.00048**** (0.00021)	**0.00042**** (0.0001)
Bundle (refrence stand alone broadband)					
Internet and voice	**0.18***** (0.02848)	**0.17***** (0.02719)	**0.17***** (0.02591)	**0.17***** (0.02372)	**0.15***** (0.01482)
Internet and tv	**0.19***** (0.04024)	**0.20***** (0.03544)	**0.20***** (0.03318)	**0.21***** (0.03008)	**0.18***** (0.02804)
Internet, voice and tv	**0.36***** (0.05198)	**0.34***** (0.04016)	**0.34***** (0.03795)	**0.34***** (0.03351)	**0.31***** (0.01743)
VoIP	**-0.073** (0.04870)	**-0.077** (0.04668)	**-0.072** (0.04296)	**-0.063** (0.03831)	**-0.078***** (0.0232)
Incumbent	**0.15***** (0.03165)	**0.14***** (0.03282)	**0.14***** (0.03265)	**0.12***** (0.03099)	**0.15***** (0.01836)
HHIPlat		**0.0014** (0.00110)	**0.00089** (0.00116)	**-0.00016** (0.00080)	**-0.00035** (0.00113)
Bitstream		**1.1***** (0.25199)	**1***** (0.23629)	**0.96***** (0.21353)	**0.99***** (0.11317)
Direct Access		**-0.16***** (0.05061)	**-0.14**** (0.04868)	**-0.092*** (0.04770)	**-0.073**** (0.03442)
Ownnetwork		**0.004** (0.01470)	**-0.00062** (0.01290)	**-0.0095** (0.01254)	**-0.0099** (0.01112)
PDispersion		**0.022***** (0.00710)	**0.02***** (0.00625)	**0.017***** (0.00530)	**0.02***** (0.00327)
Noffers Incumbent		**0.0023** (0.00222)	**0.0043*** (0.00225)	**0.0081**** (0.00409)	**0.0026** (0.00289)
R^2	*0.48*	*0.52*	*0.53*	*0.51*	*0.49*
Number of observations (N)	*2204*	*2204*	*2204*	*2204*	*2204*

Note: Robust standard errors are in parenthesis. Significance at * 10%, ** 5%, *** 1% levels.

The estimates of the pricing equation are robust to the alternative specifications. Most of the coefficients in the regressions are significant and their signs are in line with our predictions.[16] As expected, *Speed* increases broadband prices. Specifically, a 10 Mbps increase in speed raises broadband prices by an average of around 5%. However, the negative sign of *Speed*^{2} reveals that price exhibits diminishing returns with respect to speed.

Additionally, after controlling for other characteristics of the plans, xDSL appears to be more expensive than cable and FTTH. Fibre and cable technologies can provide higher speeds and better quality than xDSL, but it seems that this is not sufficient to enable entrants to charge higher prices per Mbps than are charged for xDSL. Such a situation can constitute an obstacle to the authorities' objective of promoting investment in Next Generation Access Networks (NGAs). This finding might be justified by the fact that xDSL is often the only available technology in many regions and locations and as a consequence incumbents fix uniformly higher prices for low speed offers per Mbps than those set by cable and fibre operators, who tend to be present only in densely populated areas where there are several competitors.

As for the operators' commercial strategies, unlimited plans (flat rates) charge higher prices than metered plans. In the case of metered offers, when the volume cap is exhausted the average increase in the price for an extra GB is slightly lower than 0.05%. On the other hand, bundles of services are more expensive than stand-alone broadband plans. Offers combining broadband access and TV are more expensive than those that bundle broadband access and voice telephony. Specifically, broadband packages with voice or TV are 15 and 18% more expensive, respectively. When the offer includes both voice

[16] We test for multicollinearity using the *variance inflator factor* (*VIF*). Its mean equals 1.9 and the two highest values are 4.9 for *Speed* and 3.4 for *Speed*^{2}; the rest of the VIF values are below 3.

telephony and television, prices rise by about 30%. By contrast, offers that include broadband and voice can be up to 7% cheaper if the voice service is supplied over IP (*VoIP*).

In the case of the competition variables, incumbents' plans are around 15% more expensive than entrants' offers, which might reflect the formers' dominant position in the market and "unobserved" quality differences as perceived by consumers. *PDispersion* and *Noffers* exhibit a positive effect on prices, which suggests that when firms are better able to screen consumers they set higher prices, and that a large number of plans of varying characteristics and prices might generate a certain confusion among consumers, thus, allowing firms to set higher prices (Hoernig, 2001). We also find that technological concentration, measured with the variable *HHIPlat*, does not have a significant effect on prices.

Our estimates show the entry pattern to be an important determinant of broadband prices in a country. While the intensity of *Bitstream* entry increases prices, *Direct Access* (LLU) reduces them, and *Ownetwork* does not entail a significant effect. On the other hand, the coefficient associated with *Bitstream* is higher than that associated with *Direct Access*, indicating that with an equivalent variation in the index there will be a greater price reaction with *Bitstream*. One explanation is that LLU allows operators to differentiate their products and to develop their own commercial strategies, which may avoid large price reductions for equivalent levels of entry.

As expected, the OLS estimate shows that the *Penetration* variable has a negative effect on prices. However, OLS may produce biased estimators if price and penetration are determined simultaneously. To account for this, we applied the instrumental variable approach (2SLS) using as our instrument a combination of the previously defined socio-economic variables *GDPpc*, *Density*, *Education* and *Unemployment*.

Table 4: Endogeneity test for *Penetration*

Hausman endogeneity test. Ho: *Penetration* exogenous	p-value= 0.0000		
Instruments for *Penetration*	*GDPpc, Unemployment*	*GDPpc, Education, Density*	*GDPpc, Education, Density, Unemployment*
Test	**Test Result 1**	**Test Result 2**	**Test Result 3**
Hansen J test. Ho: instruments exogenous	p-value=0.1162	p-value=0.1691	p-value=0.1140
Validity of Instruments Ho: weak instruments	p-value=0.1489	p-value=0.0001	p-value=0.0001

Table 4 presents the result of the Hausman test that confirms that *Penetration* is an endogenous variable. It also shows the results of the validity tests for different combinations of instruments. The instruments in the second and third specification pass the Hansen's J test for over-identifying restrictions and are also shown to be suitable for explaining *Penetration*. However, the validity test results for *GDPpc* and *Unemployment* (Test Result 1) are not satisfactory. Moreover, Hansen's J test value for the third specification is lower than the second value. Therefore we use *GDPpc*, *Density* and *Education* as our instruments.

Finally, we apply the instrument suitability tests (the F-statistic in the first stage regression of the variable *Penetration*) to verify that the instruments are strong. Additionally, the computed standard errors are robust to any bias from heteroskedasticity and they are also clustered according to observations from the same country.

Usually, in simultaneous equation models (SEM), the variables determined simultaneously (in this case, *Price* and *Penetration*) are correlated with the error term in the regression, causing the OLS coefficients to be biased and inconsistent. To overcome this problem, we have also estimated the pricing equation using 3SLS, which is a more efficient method[17].

The results of the 2SLS and 3SLS estimations are shown in columns 4 and 5 in Table 3. We find that the technical, commercial, and competition coefficients are robust to the use of these estimation techniques. In the case of *Penetration* the sign of the coefficient is maintained, but its value is higher than that obtained with the OLS regression. In the case of the 3SLS-IV regression, the coefficient $\tilde{\beta}_{P\text{-}3SLS}$= -0.019 implies that a one-percentage-point increase in the penetration level is followed by a 1.9% fall in price. The negative estimate of *Penetration* instrumented through the socio-economic variables more than triples the OLS coefficient, showing that the OLS *Penetration* coefficient was downward biased.

We also considered the effect of using the lagged *Penetration* variable as our instrument, where *LagPenetration* and *Lag2Penetration* are defined as the variable lagged one and two periods, respectively. Table 5 shows the Hausman endogeneity test for the lags of *Penetration.* Both variables are endogenous but their Hausman chi-square test values are lower than that for *Penetration.* The latter can be accounted for by the fact that prices and the subscription decision are determined in the same period and, as such, the simultaneity problem should be reduced for lagged periods of penetration. We ran the same OLS regression as specification 3 in Table 3 and found that the coefficient is $\tilde{\beta}_{LagPenetration\text{-}OLS}$= -0.007 when we consider one lag and $\tilde{\beta}_{Lag2Penetration\text{-}OLS}$= -0.0076 when we consider two lags of *Penetration,* and in the two cases the coefficients are significant at the 5% level. These results confirm that the simultaneity bias is downwards.

Table 5: Endogeneity test for *Penetration* and Lags of *Penetration*

Hausman endogeneity test. Ho: *Penetration* exogenous	Chi2(1)= 38.345 (p-value = 0.0000)
Hausman endogeneity test. Ho: Lag*Penetration* exogenous	Chi2(1)= 31.801 (p-value = 0.0000)
Hausman endogeneity test. Ho: *Lag2Penetration* exogenous	Chi2(1)= 7.725 (p-value = 0.0054)

6. Discussion

Below we discuss in greater detail two key features that affect the operators' commercial policies: their bundling strategies and entry patterns.

Bundling strategies - A commercial strategy widely adopted by telecom operators in the EU is that of bundling several services together in the same offer. Our analysis shows how each additional service in such a bundle increases the price of the broadband plan. However, standalone broadband and bundled offers can be considered as different products and operators price them differently. To account for this possibility, we present

[17] The 3SLS estimation of the model takes into account the structural equations for both *Price* and *Penetration* and uses the cross-equation correlation of errors to provide more efficient estimators than the 2SLS estimation. The procedure involves an additional step to the 2SLS procedure: namely, it uses the residuals from both the *Price* and *Penetration* structural equations to construct a covariance matrix of errors that provides a more efficient estimation.

separate estimations for standalone broadband and for the bundle of broadband and voice services[18]. Table 6 shows that these new estimations are very similar to those found when we consider all offers. In the 2SLS and 3SLS estimations, *Penetration* is still instrumented by the socio-economic variables *GDPpc*, *Density*, and *Education*, but its coefficient is no longer significant[19]. By contrast, *HHIPlat* is now significant, indicating that a higher concentration of one technological platform (less inter-platform competition) raises prices. In the case of bundles, this result might be further reinforced because cable and FTTH are more likely to offer TV than is the case with ADSL. As a result, technological concentration generates higher prices for bundled offers.

Table 6: Estimation Results: Standalone Broadband and Bundles. OLS; 2SLS/3SLS-IV

Dependent variable	**Stand-alone Broadband**			**Bundle: Broadband + Fixed Voice Telephony**		
Log Price (*price*)	**OLS**	**2SLS-IV**	**3SLS-IV**	**OLS**	**2SLS-IV**	**3SLS-IV**
Independent variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Penetration	**-0.0019**	**0.0036**	**0.0038**	**-0.0038**	**-0.0041**	**-0.0057**
	(0.00331)	(0.00824)	(0.00919)	(0.00229)	(0.00831)	(0.00899)
Speed	**0.0088*****	**0.0096*****	**0.01*****	**0.0071*****	**0.0070*****	**0.0075*****
	(0.00185)	(0.00160)	(0.00144)	(0.00185)	(0.00239)	(0.00215)
Speed^2	**-1.5e-05***	**-1.6e-05***	**-1.9e-05*****	**-1.7e-05***	**-1.6e-05***	**-2.3e-05*****
	(0.000005)	(0.000005)	(0.000003)	(0.000008)	(0.000008)	(0.000008)
Technology dummy (reference xDSL)						
Cable	**-0.18*****	**-0.17*****	**-0.12*****	**-0.11****	**-0.11****	**-0.08*****
	(0.05689)	(0.05295)	(0.02962)	(0.05119)	(0.04786)	(0.02969)
FTTx	**-0.17****	**-0.15****	**-0.09****	**-0.086**	**-0.087***	**-0.057****
	(0.07424)	(0.06814)	(0.04334)	(0.06263)	(0.05163)	(0.03739)
Metered offer (Data cap)	**-0.15***	**-0.14****	**-0.1*****	**-0.2****	**-0.2*****	**-0.18*****
	(0.07203)	(0.07050)	(0.03117)	(0.07460)	(0.07306)	(0.02791)
Volume cap	**0.0003**	**0.0003**	**0.00022**	**0.0006****	**0.0006*****	**0.00055*****
	(0.00030)	(0.00029)	(0.00014)	(0.00023)	(0.00021)	(0.00015)
VoIP				**-0.038**	**-0.038**	**-0.043**
				(0.03779)	(0.03572)	(0.02913)
Incumbent	**0.11****	**0.12****	**0.14*****	**0.18*****	**0.18*****	**0.2*****
	(0.04379)	(0.04662)	(0.02936)	(0.04249)	(0.03574)	(0.02773)
HHIPlat	**0.0016***	**0.0021*****	**0.0024****	**0.0042***	**0.0042***	**0.004****
	(0.00077)	(0.00066)	(0.00113)	(0.00217)	(0.00218)	(0.00131)
Bitstream	**0.89*****	**0.93*****	**0.96*****	**0.86*****	**0.86*****	**0.86*****
	(0.27161)	(0.22084)	(0.18773)	(0.21209)	(0.20025)	(0.14252)
Direct Access	**-0.1**	**-0.12****	**-0.11****	**-0.17*****	**-0.17*****	**-0.16*****
	(0.06613)	(0.05136)	(0.04758)	(0.03608)	(0.03444)	(0.04247)
Ownnetwork	**-0.0058**	**0.00057**	**0.0036**	**-0.019**	**0.02**	**0.022**
	(0.01037)	(0.01428)	(0.01491)	(0.08236)	(0.08320)	(0.05283)
PDispersion	**0.023*****	**0.026*****	**0.029*****	**0.022*****	**0.022*****	**0.022*****
	(0.00649)	(0.00711)	(0.00568)	(0.00693)	(0.00734)	(0.00458)
Noffers Incumbent	**-0.00044**	**-0.0028**	**-0.0094***	**0.0075***	**0.0075***	**0.0052***
	(0.00383)	(0.00372)	(0.00487)	(0.00412)	(0.00415)	(0.00307)
Regional Effect (reference Region 1)						
Region 2	**-0.21*****	**-0.22*****	**-0.21*****	**-0.24*****	**-0.24*****	**-0.24*****
Region 3	**-0.41*****	**-0.41*****	**-0.39*****	**-0.42*****	**-0.42*****	**-0.42*****
Time dummy (reference t=2008)						
t=2009	**0.071**	**0.069**	**0.064****	**0.061**	**0.061**	**0.059****
t=2010	**0.081**	**0.079***	**0.072****	**0.12****	**0.12****	**0.12*****
t=2011	**0.11****	**0.11****	**0.097*****	**0.15****	**0.15****	**0.15*****
Cosntant	**3.1*****	**2.9*****	**2.9*****	**3*****	**3.1*****	**3.1*****
R^2	*0.42*	*0.42*	*0.40*	*0.58*	*0.58*	*0.57*
Number of observations (N)	*909*	*909*	*909*	*699*	*699*	*699*

Note: Robust standard errors are in parenthesis. Significance at * 10%, ** 5%, *** 1% level.

[18] In the case of bundle offers, we are unable to identify the price of each particular service, but we can observe how the price of an offer increases as other services are integrated. Wallsten and Riso (2008) also adopt this approach when analyzing bundling.

[19] The penetration information we use is based on the whole sample since it is not possible to distinguish between penetrations rates that depend on bundled plans, on the one hand, and those that depend on unbundled plans, on the other.

We are also interested in identifying the factors that serve as incentives for operators to commercialise bundled services, since significant differences can be observed across European countries (Table 2). In order to address this question we run logit and probit discrete choice models that consider 1,336 observations collected on a yearly basis between 2008 and 2011. This regression focuses only on xDSL offers since bundling decisions differ substantially for cable and FTTH. For this sample, 42% of the offers are broadband standalone offers, 37% are bundles of broadband and voice, and 21% include TV, broadband and voice.

The results of the estimation for *Bundle* are presented in Table 7. As expected, *Speed* increases the probability of broadband being bundled with other services. Clearly, high download speeds are necessary in order to offer TV. However, no significant distinction is observed between the bundling strategies of incumbents and entrants. Market and technological concentration (*HHIOper* and *HHIPlat*) are negatively associated with the probability of bundling. This suggests that bundling is used by operators to attract consumers in competitive markets, whereas in more concentrated markets operators prefer to sell additional services separately. We also consider the effects of price dispersion and find that it increases the probability of bundling. Therefore, in markets with a wide-range of prices, operators might commercialise bundles of services to differentiate their plans. Finally, no correlation is found between bitstream and direct access and bundling, although bundling is found to be less likely in markets where more entrants bypass the incumbent's network (own network).

Table 7: Logit/Probit for Bundling

Dependent variable		
Bundling	**Logit**	**Probit**
Independent variables	**Coefficient**	**Coefficient**
Speed	**0.033***** (0.00827)	**0.02***** (0.004516)
Incumbent	**0.38** (0.2556)	**0.23** (0.15672)
HHIOperator	**-0.093**** (0.03781)	**-0.057**** (0.02286)
HHIPlat	**-0.035**** (0.01614)	**-0.022**** (0.00998)
PDispersion	**0.062*** (0.03288)	**0.038*** (0.01957)
Bitstream	**-0.9** (0.7889)	**-0.56** (0.4786)
Direct Access	**0.1** (0.4771)	**0.075** (0.2862)
Own network	**-2.8***** (0.8134)	**-1.7***** (0.5001)
GDPpc	**0.003** (0.0053)	**0.0022** (0.003317)
Education	**-0.017** (0.01455)	**-0.011** (0.00888)
Density	**0.00072** (0.00059)	**0.00045** (0.00037)
Regional Effect (ref: Region 1)		
Region 2	**-0.3** (0.3644)	**-0.19** (0.2239)
Region 3	**0.22** (0.4141)	**0.14** (0.2555)
Constant	**5.8*** (2.3438)	**3.6**** (1.4299)
Pseudo R^2	*0.11*	*0.11*
Number of observations (N)	*1336*	*1336*

Note: Robust standard errors are in parenthesis.
Significance at * 10%, ** 5%, *** 1% level.

Entry pattern - One of the main results of our analysis is that broadband prices are negatively related with LLU entry intensity, and positively related with bitstream entry intensity. This result implies that during the period analysed intra-platform facility-based-competition was more effective in reducing prices than was intra-platform service-based-competition, once we control for other characteristics of the offer. At this juncture, it should be stressed that the intensity of each country's entry pattern is influenced by the regulation of access charges. In fact, European regulators usually follow the LOI approach, which proposes setting higher prices for bitstream so as to induce entrants to use direct access (Cave, 2006; Höffler, 2007, Bourreau, Dögan and Manant, 2010). As shown in Bacache, Bourreau and Gaudin (2011), this regulatory strategy may have facilitated the migration from bitstream access lines to LLU, although their study does not find any ladder effect between LLU and entrants deploying their own network.

The regulation of access charges in the EU has been designed to provide incentives for investment by entrants; however, in this paper we have also shown that it affects retail prices. Prices are higher in countries where entrants make greater use of bitstream entry and lower in countries where they make greater use of direct access. In fact, while the establishment of high access charges for bitstream might act as an incentive to incumbent operators to set higher uniform prices for their Internet plans, the establishment of low access charges for direct access might not result in an equivalent response by operators, since this type of entry requires major investment and because it allows operators to differentiate their product (Nardotto, Valletti and Verboven, 2012). This situation is reflected in our estimates of the *Bitstream* and *Directaccess* concentration indexes, since the value of the coefficient is much greater for the former than for the latter. For instance, in specification 5, $\tilde{\beta}_{Bitstream\text{-}3SLS}=0.99$ and $\tilde{\beta}_{Directaccess\text{-}3SLS}=-0.073$, which reflects the greater increase in prices due to bitstream concentration than the relative decrease due to LLU concentration.

Our results also suggest that inter-platform competition does not affect significantly retail prices. Entrants that invest in cable and FTTH networks are able to commercialise high-quality services, but this does not necessarily mean a reduction in their retail prices. Moreover, although cable and FTTH plans involve lower prices per Mbps than those charged by xDSL plans, the former typically offer more downstream speed and additional services such as TV, which increase prices. A further important aspect that should be taken into account when interpreting our results is that in our model competition is introduced at the national level, but in some countries technologies are geographically segmented and so there is little competition between them.

6. Conclusions

This paper has analysed the determinants of the prices of broadband Internet access in 15 countries of the EU between 2008 and 2011. Our econometric model has focused on three types of variable: (1) the technical characteristics of the offers; (2) the operators' commercial strategies; and (3) the regulation and competition in the country. Besides, we have controlled for the potential endogeneity of broadband penetration by using the instrumental variable approach (2SLS/3SLS) and employing as instruments a group of socio-economic variables that determine the demand for broadband services in each country.

Our analysis has revealed that downstream speed is a significant driver of price: a 10 Mbps increase in the download speed causes prices to rise by an average of around 5%. Additionally, we have found that the price per Mbps paid for the service via cable or fibre technologies is lower than that provided by xDSL, although these technologies usually provide higher download speeds. On the other hand, the xDSL service usually involves more intra-platform competition and has a wider coverage than other technologies. In this context, an important question that emerges is whether consumer willingness to pay for fibre and cable plans is sufficiently high to encourage operators to invest in NGAs.

The operators' marketing strategies also play an important role in determining prices. When the broadband service is bundled with voice telephony, the price increases by around 15% and when it is bundled with both voice telephony and television it increases by around 30%. By contrast, consumers that contract the voice service through VoIP obtain significant price reductions. We have also shown that operators are less likely to bundle their offers when the market is less competitive or when there is less inter-platform competition.

This paper has also contributed to the literature that analyzes how regulatory policy can influence the development of the broadband market. Here, we have shown that broadband prices are higher in countries where entrants make greater use of bitstream access and lower in those countries making greater use of LLU. We have found no evidence that inter-platform competition and stand-alone entry (the last rung on the "ladder of investment" approach) reduce prices. This means that when entrants bypass the incumbents' networks, retail prices are not reduced. This might be because this type of entry does not generate sufficient competition, and because the operators offer high-quality products that are more expensive. All in all, our results can be interpreted as an assessment of the "ladder of investment" approach, and they show the benefits of facilitating migration from bitstream to LLU entry.

One limitation of our study is that we have not considered mobile broadband plans offered via smartphones or dongles. Mobile broadband demand is boosting and future research needs to consider the impact of the firms' commercial strategies for mobile broadband offers. For example, a rising number of operators are currently offering bundled mobile and fixed broadband packages, which minimises the consumer churn rate (Prince and Greenstein, 2011).

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