de Barcelona

PhD in Economics | Fernando Martínez Santos

Universitat de Barcelona

PhD in Economics

Competition and Regulation in the Retail Broadband Sector: a Holistic Approach for Pricing Policies

Fernando Martínez Santos

Universitat

PhD in Economics

Thesis title:

Competition and Regulation in the Retail Broadband Sector: a Holistic Approach for Pricing Policies

PhD student:
Fernando Martínez Santos

Advisor:
Joan Calzada

Date:
May 2015

Universitat de Barcelona

Table of Contents

Chapter 1

Introduction

1. Background and motivation

The benefits attributed to the adoption of broadband Internet in a society (Crandall et al., 2007; Katz et al., 2009; Czernich et al., 2011) have stimulated national governments and international institutions to promote the diffusion of this service across all individuals, no matter their economic status or geographic location. The telecommunications market is characterised by high entry barriers, and over the course of the last few decades, regulatory bodies have implemented several policies which facilitate operators' entry (giving "entry assistance"). Most regulatory measures have been focused on the wholesale market, where lies the main 'bottleneck' (or "essential facility"), which is either very costly to replicate, or is a scarce resource (Renda, 2010; Bouckaert et al., 2010). The principal focus here is that it is essential to reach competition upstream so as to have a competitive retail market which, in turn, stimulates broadband penetration.

One of the main measures of the intensity of competition in a market is the level of retail prices, which is also an important determinant for the adoption of the Internet by consumers.[1] At the beginning of 2014, and following the publication of a European Commission (EC) report on Internet prices across the EU, [2] the Commissioner Neeli Kroes expressed her concerns over the large discrepancies (up to 400%) in retail broadband prices across EU countries, claiming this was a signal that there is not a single market for the Internet. In spite of this, apart from the price benchmarking reports published by regulatory authorities and organisations, the literature on the broadband market has offered very little attention to the establishment of the

[1] According to the *Special Eurobarometer* (2014), price was the most important factor when in it comes to choosing an Internet connection (71%). See: http://ec.europa.eu/public_opinion/archives/ebs/ebs_409_en.pdf

[2] *Broadband Internet Access Cost* report for year 2013 (BIAC 2013) See: https://ec.europa.eu/digital-agenda/en/news/study-retail-broadband-access-prices-2013-smart-20100038)

prices of this service, possibly due to a lack of consistent datasets and the inherent difficulties in measuring the price of a heterogeneous service. On the other hand, existing papers which have studied broadband prices (Wallsten and Riso, 2010; Greenstein and McDevitt, 2011) have mostly taken a hedonic approach to the analysis of broadband prices, but have not studied how the market structure and regulatory policies affect retail tariffs.

The inflexion point towards greater competition in the telecommunications market started with the liberalization of telecommunications services in the US in 1982 with the breakup of the ex-monopoly telecoms operator AT&T (Renda, 2010). As result of this, an extensive body of literature has arisen around the "essential facilities" doctrine, which considers that if a firm controls an input or an asset that is essential to its competitors, it must provide access to this essential facility when the replication is impossible or too costly from a legal, structural, or economic point of view (Hovenkamp, 2008). In the last years, an important part of the regulatory policies in the telecommunications sector have focused on facilitating entrants' access to this essential facility in order to stimulate competition, thereby leading to higher penetration levels. However, the application of the essential facilities doctrine is very dynamic in the telecommunications market, making it hard for policy makers to set the right obligations of access to the essential input in order to avoid bottlenecks or market foreclosure. On the other hand, it is difficult to promote entry in the short term while at the same time encouraging firms to invest in the medium/long-term future.

In most countries, while the wholesale broadband market is strongly regulated, regulation in the retail market is scarce, and reduces to ensure that incumbents do not abuse their dominant position. For example, "margin squeeze" tests study the replicability of an incumbent's plans in such a way that there is a sufficient margin between its upstream and downstream prices. This means that entrants are then able to match the incumbent's retail prices. In the fixed broadband sector, regulators have set *ex-ante* obligations on operators. In the case of the European Union, national regulators impose mandatory access to the incumbent's fixed network (the bottleneck) and set the network access prices paid by entrants to the incumbent, thereby supporting wholesale competition which, in turn, should also stimulate retail competition. In the mobile market, regulators have fostered entry by regulating the costs of terminating phone calls (Mobile Termination Rates, MTRs) on a different operators' network, and by forcing mobile operators with their own network (MNOs) to make their networks available to entrants (in this case, spectrum frequencies constitute the bottleneck). This has allowed the creation of the so-called mobile virtual network operators (MVNOs).

The intervention of governmental institutions in the telecoms industry has been a key factor in explaining the current market structure and the progress of communications services. The market has evolved from a situation where a monopolistic firm provided all the communication services, to an oligopoly setting in which several communications firms play a role. In this context, service diffusion and competition has significantly strengthened, and telecoms operators have adopted "innovative pricing plans" to segment consumers, attract new subscribers and build customer loyalty (Srinuan et al., 2012). In this sense, they have implemented different commercial strategies such as tiered pricing (e.g.: according to data volumes or connection speeds), premiums charges on new technologies (e.g.: 4G mobile technology), or bundling (e.g.: commercializing together broadband with voice services).

The three chapters of this dissertation share a common thread in that they analyse the pricing policies used by operators when they establish the tariffs of their plans. The price drivers are grouped into three categories: 1- the characteristics of the broadband service, 2- the operators' commercial strategies, and 3- the market structure and regulatory policies implemented. In order to estimate the pricing equation I begin by first applying a hedonic approach with only the characteristics of the broadband service evaluated. And afterwards the pricing model evolves to analyse the prices from a holistic point of view. Indeed, the models use the described three groups of variables that might affect the level of prices paid by the end-consumer. The methodologies used in the research of price drivers also share the characteristic of using two econometric techniques for panel data: ordinary least squares (OLS) with fixed effects, and two stage least squares (2SLS, instrumental variable techniques).

The first empirical study uses data on fixed broadband plans from 15 EU countries from 2008 to 2011, while the second covers mobile broadband plans from 37 countries all across the globe from 2011 to 2014. Both datasets are combined with data from other public sources to add socioeconomic control factors to the models. The last chapter analyses in depth the evolution and current state of the mobile broadband sector in Spain up until 2014.

All in all, this dissertation focuses particularly on retail prices in order to measure competition in the telecommunications sector, and uses the variability of broadband features, market structure, as well as regulatory indicators across countries and time periods, to reveal insights into the drivers of these price structures. As previously mentioned, the level of broadband prices concerns both national governments and international organisations, and this dissertation should help to provide some guidance to regulators and competition authorities, helping them in the implementation of policies so as to foster competition in the market and ultimately stimulate the diffusion of broadband services.

This introductory chapter is divided in three sections. Section 2 provides an overview on broadband services and technologies. Section 3 describes the regulation implemented within this sector, emphasizing the regulatory policies that have been crucial in Europe. Then, section 4 undertakes a revision of economic literature on the broadband sector, focusing on the previous research which has most served to develop this dissertation. Finally, section 5 provides a brief summary of the three chapters of my dissertation and describes the main contributions of each chapter.

2. The Internet service and broadband access

The Internet has been one of the principal technological advances in the transformation of society over the last few decades, not to mention the main driver of information and communications technologies (ICTs) over the same period. Indeed, the Internet has completely modified our way of working, and has contributed to innovation in several markets (e.g. healthcare and education). It has also increased productive efficiency and growth in general (ITU, 2003a; Cradall et al, 2007; Czernich, 2011). Moreover, the Internet has changed society in terms of personal relationships, information access, and entertainment (Rajani and Chandio, 2004; Amichai-Hamburger and Hayat, 2013).[3]

[3] Some studies have highlighted the addiction to Internet might have negative effects in individuals such as isolation, and worsen physical or emotional health (Kraut et al., 1998; Kehoe et al., 2009).

The Internet's development started in the 1960s and was implemented for first time in 1969, when four host computers were combined together into the initial ARPANET (Advanced Research Projects Agency Network), allowing data communications (packet switching) between three universities in California and one in Utah (US). The first Internet Service Providers (ISPs) appeared at the end of the 1980s and beginning of the 1990s. They offered new interconnection facilities and graphic tools across the network, and promoted Internet services to the mass population. The Internet, as a system of interconnected computer networks, was converted into a global information service, as well as a medium of interaction between individuals no matter their location, thanks to a range of websites ('WWW' navigation) contained in numerous servers, of which the network is comprised (Kleinrock, 2005; Leiner et al., 2012).

The term 'broadband' was traditionally applied to Internet connections that allowed for data transmissions faster than the previous dial-up or ISDN (Integrated Service Digital Network) technologies (Cava and Alabau, 2006). The download (upload) speed data transmission threshold that has been adopted to define broadband by international institutions such as the OECD or ITU is 256 kbps (ITU and UNESCO, 2014), whereas the European Commission sets 144 kbps as the minimum speed (EC, 2009a; BIAC, 2012). The definition of broadband access to Internet varies across institutions and has evolved over time. In this respect, the Federal Communications Commission (FCC) has recently defined broadband as Internet data transmissions that allow the end-user to download content at 25 Mbps (3 Mbps upload), much higher than its previous definition of 4 Mbps (1 Mbps upload).[4] Although it is obvious that broadband technologies and digital content evolve quickly, one of the problems inherent in changing the definition of broadband is that data becomes more difficult to compare across time.

The development of high speed Internet connections heralded the start of the broadband service, which was referred to in name for the first time in 1988 by the ITU, when it was defined as "qualifying a service or system requiring transmission channels capable of supporting rates greater than the primary

[4] See FCC news January 2015: http://www.fcc.gov/document/fcc-finds-us-broadband-deployment-not-keeping-pace

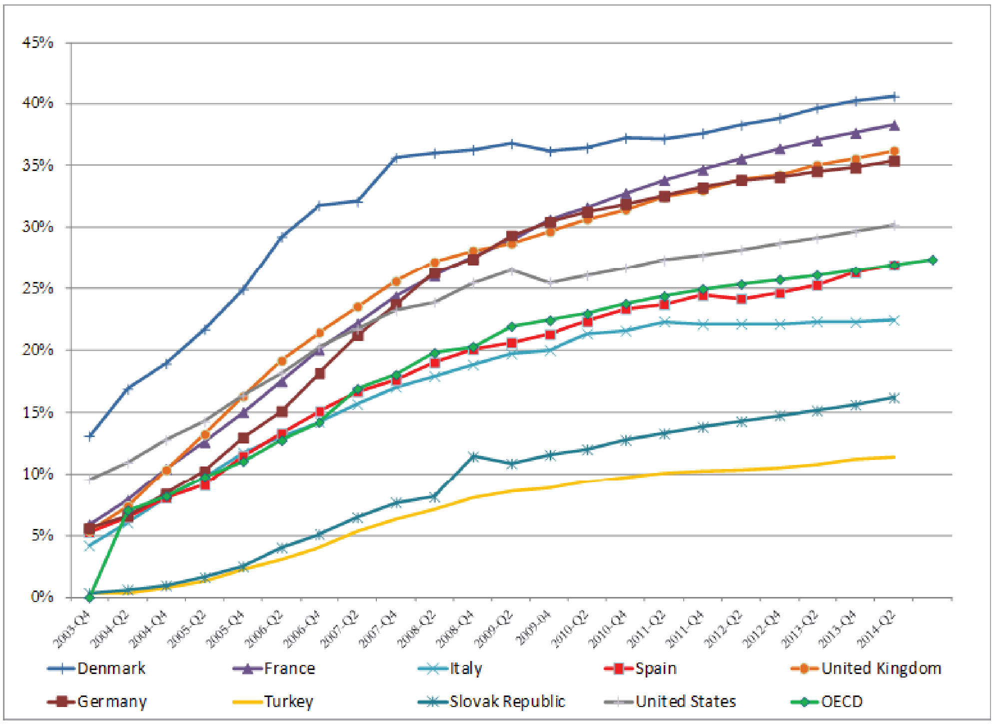
rate". [5] At the end of the 1990s, broadband connections had allowed much higher data transmission rates than dial-up, thereby boosting Internet usage. The diffusion of the Internet (Fig. 1) as a global communications service has been very rapid since the onset of broadband access. Since 2000, the broadband service has experienced strong growth. While there were 83 million broadband subscribers in the OECD countries by the end of 2003, by June 2007 subscriptions had grown by 165% to 221 million lines (OECD, 2008). At present, broadband continues its expansion, with much higher transmission rates supported by new generation access networks (NGANs) such as fibre and 4G technologies, which allow for numerous and more sophisticated services. In recent years, broadband diffusion has been led by mobile technologies. According to the OECD, by the middle of 2014 there were 344.6 million fixed broadband lines, and the number of mobile broadband lines had reached 983 million in OECD countries. Most of these mobile broadband subscriptions (around 85%) were on smartphone and tablets, while less than 15% were data dedicated services using modem USB devices (OECD, 2015).

Despite the rapid growth of the broadband service, there is a big debate about the inequality of broadband adoption. It has also been argued that some countries or customer segments are experiencing lower adoption rates than is desirable, and suffer from the so-called "digital divide" which claims that some individuals are marginalised from digital services, as is evidenced by the gap in digital technologies between developing and developed countries (EC, 2012a; ITU, 2014). For this reason, many international institutions and national governments have declared the Internet essential to our society, and have designed strategic plans so that all citizens have access to broadband services (ITU, 2014).

---

[5] The use of Internet became very popular with the dial-up access in the nineties. At the beginning of the 21st century, many consumers in develop countries used the Internet access at high speeds. From 2014, broadband is a ubiquitous service over around the world, with an average speed connection over 4Mbit/s (Akamai, State of the Internet Report 2014).

Figure 1: Broadband penetration for the OECD average and a sample of OECD countries.



Source: OECD

2.1. Broadband technologies

The first Internet connections were fixed narrowband technologies; these are the dial-up modems and ISDN connections which allowed for download speeds up to 56 kbps and 128 kbps respectively. Both technologies used the old copper telephone lines, but while dial-up was an analog system that did not allow for simultaneous voice and data transmissions, ISDN technologies were digital and the simultaneity of data and voice transmissions was possible.

The emergence of fixed broadband Internet occurred with the development of new technologies that allowed for high speed data transmission rates (Papacharissi and Zaks, 2006). Nowadays, the most widespread broadband technology is DSL (Digital Subscriber Line) which in 2014 represented around 50% share in OECD countries. These technologies are based on the conversion of telephone copper lines to a digital line using a wider spectrum of frequencies, which allows for the simultaneity of Internet and voice transmissions (the "always-on service"). There are various forms of xDSL technologies, which evolved from Asymmetric DSL (ADSL) into more advanced modes: High Rate DSL (HDSL), Symmetric DSL (SDSL) and Very High Data rate DSL (VDSL). DSL download (and upload) technologies are able to provide connection speeds ranging from 256 kbps to 52 Mbps, although these speeds depend on the physical distance of the user to the telephone exchange (this is why it is so often called the "last-mile technology").

The fibre technology corresponds with a NGNA (new generation access network), which in 2014 represented around 15% of total fixed broadband connections in OECD countries. Cable modem, which uses access lines for cable television (or Community Antenna Television, CATV), represented around 30% of the total fixed broadband connections and is able to provide higher download and upload speed rates than the original DSL technologies, and its speed depends much less on the physical location of the customer. Moreover, the upgrade of cable TV networks, referred to as DOCSIS 3.0 technology, allows for higher bandwidths of 150 Mbits/s and more. Fibre optic technologies (FTTx) allow for transmission speeds of up to 1 Gbps. There are also different types of fibre technologies depending on whether the wire in "last mile" is made from fibre or copper. Therefore, FTTN (fibre to the node), FTTC (fibre to the cabinet), FTTB (fibre to the building), and FTTH (fibre to the home), are all deployments which use fibre. However, the distance of the fibre network becomes a step closer to the premises from FTTN to FTTH, and for FTTH the "last-mile" is made entirely of fibre. FTTH is also the technology that provides the highest speed connections (OECD, 2012).

Other less common technologies include satellite and WiMax, which are wireless technologies used for fixed broadband connections. Another method, BPL, is broadband using power lines. These technologies are primarily used to provide coverage to remote areas within a country.

Lastly, since the appearance of 3G mobile technologies at the beginning of this century, mobile broadband has become the fastest-growing communications technology, both in terms of subscribers and data traffic (Cisco, 2015). Most mobile broadband plans nowadays are used via smartphone or tablet devices, making up around 85% of the total mobile broadband connections in OECD countries, while the remaining 15% are data dedicated service; datacards used via USB modems which have experience a relative decline recently.

The first mobile technology was launched in Japan at the end of the 1970s, a 1G technology that allowed only voice and text messages. The capabilities of the Internet on mobile devices developed thanks to the evolution of analog mobile standards of voice (1G technology) to digital standards such as GSM or GPRS, which allowed for voice and data transmissions (2G). GSM was launched in 1991 in Finland and expanded quickly to other countries.

Interestingly, Europe used different and incompatible standards for 1G technology and a single standard (GSM) for 2G technologies; the US, on the other hand, did the opposite (a single standard for 1G and multiple standards for 2G). These two different strategies also seem to have had different effects on the diffusion of the service, and would seem to favour the positive impact of single standards in order to obtain higher mobile broadband penetrations. As a result, in 1997, of the 40 million 2G subscribers, more than 80% were GSM subscribers (Gruber, 2005; ITU, 1999).[6]

Later, the emergence of 3G standards for first time in Japan in 2002 announced the 'birth' of the mobile broadband service. 3G technology started soon after in Europe, and later on in the US. The unsuccessful launch of 2G technologies in the US caused mobile penetration to slow down. 3G technologies such as UMTS or WCDMA enable transmissions of a few Mbps, and soon started to be used on smartphones (SIM card) and laptops (through modems USB). New advances in 3G technologies, such as 3.5G and 3.75G, enabled download speeds of several Mbps, and HSPA+ is able to reach similar speeds as those offered by LTE (4G) technology. Indeed, 4G technology, which was launched in 2008, has significantly increased speed rates (and also the volume of consumption in gigabytes); up to 150 Mbps for download, and up to 50 Mbps to upload data, narrowing the speed gap that exists between fixed and mobile broadband technologies (Kumar et al., 2010; Lee et al., 2011). This situation might facilitate some substitution of fixed for mobile broadband in the years to come (Nakamura, 2015).[7] Finally, the launch of the

[6] After the creation of the *European Telecommunications Standard Institute* (ETSI) in 1988, the release of the GSM standard (2G technology) reflected the commitment between policy makers of creating standards for ICT technologies that were globally compatible.

[7] In Europe, there were a total of 10 million of lines connected to Internet via LTE by

next 5G technologies is expected by 2020, and transmission speed rates with this new generation technology will surpass 20 Gbps.

3. Regulation of the broadband service in Europe

3.1. Background: the liberalisation of the telecoms industry

In the last five decades, the telecommunications market industry has been continuously affected by regulation interventions ("antitrust policies") aimed at introducing more competition in the market. A monopoly might have some advantages of lowering costs thanks to economies of scale (lower average costs when higher quantities are produced) and scope (efficiencies created when a single firm produces goods with common features); this is the "natural monopoly" theory. Indeed, under circumstances where fixed costs are high, it might be less costly for a single firm to produce the same or multiple goods, rather than a number of firms. However, the existence of a monopoly also makes it more likely that the single firm abuses its dominant position. Consequently, there is a loss of efficiency. In this situation, regulation of natural monopolies can be seen as a measure to avoid the disadvantages associated with the abuse of "significant market power", while maintaining the production efficiencies associated with a single firm serving the market.

For a significant period of time during the twentieth century the telecommunications market was regulated, and was dominated by public monopolies which were sustained on the grounds of financeability (high sunk investment costs) and the universalization of public utilities. From the 1970s onward, the telecommunications market structure changed radically when a new wave of economic theories and business forces supporting deregulation (Stigler, 1971), coupled with technological progress, transformed the telecommunications market. The liberalisation of the market started in the US in 1982, when the integrated telecommunications monopoly AT&T had to open its network to other independent operators. Later, in 1984, the *Modified Final Judgment* (judge Harlod Greene) required the divestment of the company. Following the US example, similar changes extended to other countries,

September 2013 and a total of 91 operators had started providing LTE to their customers. According to Cisco (2013) the traffic in mobile networks is expected to increase yearly by 66% in the period 2012-2017.

starting in the United Kingdom with the privatisation of BT, which spread to Chile, Japan, and New Zealand (Calzada and Costas, 2014). In the US, at the end of the eighties the regulation of the sector was primarily focused on the incumbent operator, with the objective of promoting entry and incentivizing consumers to switch to new market entrants. The next step in the liberalisation process took place in 1996 with the launch of the *Telecommunications Act* in the US, which liberalized completely the market. This regulatory followed a regulatory approach based on the "essential facility doctrine" and aimed at promoting intra-platform competition, with the imposition of network interconnection between entrants and the incumbent operator, and the wholesale access to the incumbents' networks at regulated rates (unbundling of the local loop, ULL) (Renda, 2010). Also, the *Telecommunications Act* set the necessary context needed to support the "universal service", which was one of the most important claims of those that were in favor of a monopolistic market.[8] Nevertheless, at this stage there was still not a clear system of how to correspond the level of the interconnection prices with the costs of providing the access (Rickford, 1998).

In 1987, sometime after the liberalization of the US and the UK markets, the EC proposed a new regulatory framework[9] aimed at opening up the national EU markets for telecommunications equipment and services. The liberalisation process was seen as a challenge, and the EU also feared that the European economy could become less competitive in comparison to the US. In addition, the arrival of US businesses to Europe stimulated the full liberalisation process of the EU telecoms market, which eventually happened in 1998 with a regulatory package that set a wide programme of policies aimed at creating a single telecommunications market and introducing competition (Calzada and Costas, 2014). This regulatory package had to be adopted by the National Regulatory Authorities (NRAs) in each EU country, but the EC may veto the NRAs decisions on the scope of the geographic market and the identification of "significant market power" (SMP). Moreover, the EC 1998 regulatory framework established the boundaries between 'ex ante' regulation and 'ex post' competition law enforcement. Later, in 2002 a "new" regulatory framework based on the anti-trust methodology was implemented to tackle the problems of a lack of efficiency associated with SMP. A pre-requisite for

[8] See https://transition.fcc.gov/telecom.html

[9] The publication of the *Green Paper* on the development of the common market for telecommunications services and equipment in 1987 set the main directions of the telecommunications policy in Europe (Gruber, 2008).

the adoption of remedies by NRAs was that these remedies have to be 'proportionate' to the existing 'inefficiencies' (or "market failure") identified by the regulator. By proportionality the EC states that a remedy (e.g. a divesture) cannot be made if it does not effectively address competition concerns, and the EC will prioritise the less burdensome remedy for the firms (EC, 2012). Finally, a substantial reform was made in 2009 when the EC updated the 2002 regulatory package by implementing a group of amendments on both the existing policies and new ones, such as facilitating the operators' access to the radio spectrum, as well as measures to increase the level of consumer protection. The new regulatory reform also included the establishment of an independent "Body of European Regulators of Electronic Communications" (BEREC) to build on the increased independence of NRAs and improve existing coordination mechanisms (EC, 2007; Alabau and Guijarro, 2011).

3.2. Regulation of the broadband market in the EU

After the liberalisation of the European telecoms market at the end of the 1990s, the EU enforced mandatory access to the incumbent's network so that new entrant operators were capable of providing communications services after paying an interconnection access fee to the incumbent.[10] One of the most important EC Directives is the *Interconnection Directive* (1997)[11] which places a series of obligations on operators with significant market power, making it mandatory for them to set interconnection charges that are transparent and cost orientated, whilst including a reasonable rate of return (the EC recommended the NRAs use of the *Long Run Incremental Costs*, LRAIC).

European regulatory policies on the broadband sector are mainly focused on the wholesale market.[12] Thus, the EU's approach is to combine intrusive regulation on the wholesale side and de-regulation in the retail market. It is

---

[10] Initially, mandatory access was adopted by the FCC but from 2003 the US telecoms regulator stopped imposing mandatory unbundling and price regulation on fibre technologies and extended it to DSL in September 2005 (Renda, 2010).

[11] http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31997L0033:EN:HTML

[12] The most important regulation ('ex post') in the downstream market is the use of "margin squeeze" tests. These tests are focused on ensuring that the proposed retail prices are not anticompetitive given the price of relevant wholesale inputs, the interconnection prices, and in order to allow entrants to be able to at least replicate the incumbent plans rather than keeping retail prices at a particular level.

expected that it will be enough to promote competition in the upstream market to foster competition and bring large benefits to consumers in the downstream market. Also, regulators might adjust the wholesale regulation depending on the development of a particular market at a certain point. For instance, the regulator may set "regulatory holidays" which means the regulator commits to a fixed period of time free of access once a new network is built. Another regulation that can be applied is the "sunset clauses", which specifies, ex ante, a period of time after which the incumbent's facilities are no longer regulated.

The regulation of the fixed broadband market which is imposed on the incumbent's network can give rise to two types of competition within the incumbent's network: "service-based" or "facility-based" intra-platform competition. Regulation at service-base level implies that either the entrant operator simply resells the incumbents services, or that it makes some investment in order to have a "point of presence" from where they connect to the incumbent's networks and offer their own broadband services. This is the so-called *bitstream* or indirect access. This type of entry does not demand a high investment, and it allows the entrant to progressively invest and climb the 'ladder' so as to reach the next 'rung', which is facility-based entry (Cave, 2006). This regulatory approach implies unbundling the local loop elements of the incumbent's network (ULL), but also requires that the entrants invest in their own equipment and facilities to provide the broadband service. We can also identify two types of direct access or ULL: i) full access (full ULL) implies that the entrants access the incumbent's lines without restrictions, and ii) shared access (shared or partial ULL) means that access is restricted to the provision of the broadband service and that the incumbent retains the line's low frequencies to offer a voice telephony service. Moreover, under shared access the entrant is still able to provide a voice service to the customer using voice over IP (VoIP), this is the *naked ADSL*. The direct access (ULL) requires additional investments compared to *bitstream,* as there are fewer points of connection to the incumbent's network (and a longer distance from these access points to the customers' premises). However, access prices under direct access are cheaper for the entrant than *bitstream*. Finally, the direct access allows entrants for a higher degree of differentiation from the incumbent's broadband plans in the retail market.

In the wireless broadband sector the main bottleneck is the radio spectrum, which is restricted to a limited number of frequencies. Governments regulate the spectrum in such a way that it can be used efficiently by operators to provide their wireless services. The allocation of the spectrum frequency bands is a two stage process (Gruber, 2008). First, the allocation of the spectrum is decided at international level by the ITU, who decides how much spectrum is allocated to a specific application (e.g. TV and mobile services). The second stage is decided by the NRAs in each country, who assign the frequencies between mobile operators. In recent years, European regulators have allocated a number of licenses by auction, thereby offering a set of frequencies of the radio spectrum.[13] Some of these frequencies were freed up after the migration from analogue to digital television, which is more spectrum efficient. This is the so-called "digital dividend" (EC, 2009b). Last but not least, since 2002 the EC has aimed to allow firms which do not hold spectrum licenses, but are willing to provide mobile services, to access the market by reaching agreements with those mobile operators "owning" a part of the spectrum (mobile network operators, MNOs). Thus, a great number of Mobile Virtual Network Operators (MVNOs) have gradually appeared in EU countries in the last decade, which have helped to foster competition in the mobile market (Kiiski, 2006; Kimiloglu et al. 2011).

4. Relevant literature related to broadband pricing policies

There is extensive literature on the regulation of broadband services and its effect on competition. Indeed, there are many studies that analyse how the regulation of the wholesale broadband access has impacted on the level of diffusion and also, more recently, on the quality of the service (e.g. higher download speeds). This section highlights the studies that have been of most importance in the economics of broadband Internet access, and which present similarities in the methodology that has been used for the development of this dissertation on pricing regulation.

[13] There is extensive literature on auction theory as well as on auctions applied to the spectrum allocation (Binmore and Klemperer, 2002; Cramton, 2013). Also, there exist other mechanisms to assign the spectrum, apart from auctions, which are: i) first-come-first served, ii) lottery, and iii) "beauty contest". As for "beauty contests", the most popular process to allocate the spectrum after auctions, the regulator first establishes the criteria and chooses the winner(s) operators according to this selection criteria (Gruber, 2008).

4.1. The impact of broadband on economic growth

The main interest for examining the drivers of broadband penetration is to analyse the positive effects of the Internet on economic growth. For example, the Internet has been crucial in the emergence of 'tele-working', transforming the way business works, and it has also launched the utilisation of virtual unilateral or bilateral platforms, for instance job market portals, putting workers and businesses in contact with one another in ways not seen previously.

Previous to the literature on broadband, Roller and Waverman (2001) analyse the impact of fixed voice telephony diffusion on economic growth, and find that around a third of the economic growth in the OECD countries is due directly or indirectly to telecommunications. However, other theories have signaled that the Internet's development can have even greater qualitative effects (e.g. information transmission) which increase competition and the development of new products and processes, such as new entrepreneurial or working methods (Fornefeld M. et al., 2010).[14]

Czernich et al. (2011) take a panel of 25 OECD countries between 1996 and 2007 and find that a 10-percent point increase in broadband penetration drives GDP per capita upwards by 0.9 to 1.5 percentage points. These authors consider broadband penetration to be endogenous in the process of economic growth, and to mitigate the consequences of endogeneity, they support their analysis with an instrumental variable estimation using existing copper telephone networks and the number of cable TV subscribers.

Another study by Koutroumpis (2009) uses the data of 22 OECD countries from 2002 to 2007 to estimate the impact of broadband infrastructure on growth. He finds a significant causal positive link, especially when a critical mass of infrastructure is reached. The causality between broadband infrastructures and economic development is also analysed in two papers on regulation (Gillet et al., 2006; Crandall et al., 2007). These studies exploit the differences in the development of the broadband service across different US states, and find a positive relation between broadband diffusion and economic growth indicators such as employment, wages, and property prices. However,

---

[14] See *The Impact of Broadband on Growth and Productivity* conducted on behalf of the European Commission by Micus Management Consulting GmbH.

these studies lack of an empirical strategy to identify the causality of broadband adoption. Previously, Crandall et al. (2002) estimated that the adoption of Internet business solutions had yielded US organisations cumulative cost savings of $155.2 billion and increased revenues of $444 billion from the first year of implementation through to 2001.

Other studies, not directly related to broadband but to technological progress in general, have analysed the effects of new technologies and their impact on GDP (Nelson and Phelps, 1996; Benhabib and Espiegel, 2005). These studies suggest that, thanks to IT, there are "information spillovers" which promote economic growth.

All in all, these findings confirm that the telecoms industry is an essential component in the economy and improves welfare significantly. As for broadband, the literature seems to find a clear relationship between broadband penetration and GDP growth. Broadband services have promoted employment and improved efficiency thanks to new working methods and processes, amongst other positive effects related to economic growth. Nevertheless, the reverse causality between broadband adoption and GDP has been an obstacle in these studies, making it more difficult to estimate the effects of broadband on economic growth.

4.2. Studies on fixed broadband diffusion

The benefits associated to broadband access have given rise to a wave of theoretical and empirical research focused on analysing the drivers that impact on broadband adoption. The national and international organisations' concerns on the so-called "broadband divide" (OECD, 1995) reflects interests in providing access to rural and remote geographic areas, or individuals with low rents who cannot access the Internet. These interests strive to help specific segments of the population avoid being excluded from the digital world, and therefore from wider society.

The diffusion models used in the literature on broadband penetration are usually either log-linear models or logistic models, which assume that the diffusion of the service follows an "S-shape" logistic curve. Griliches (1957) pioneered these logistic penetration models in his study of the diffusion of hybrid corn varieties. For instance, an early application of logistic models in the telecoms was made by Gruber and Verboven (2001), who studied the factors influencing the diffusion of mobile services in European countries from 1981 to 1997. However, in many countries the number of subscriptions exceeds the population, often by a considerable degree, indicating a tendency towards saturation in terms of primary diffusion. In these cases, the relationship between penetration and its drivers might be more linear, and hence empirical analysis might be implemented using a more traditional multivariate analysis (e.g. a 'lin-lin' or a 'log-lin' econometric model) applied on panel or cross sectional datasets.

The regulatory approach followed by the EU to regulate broadband access is based on the "ladder of investment theory", LOI, (Cave and Volgensang, 2003; Cave, 2006).[15] This theory is based on the difficulties to replicate the incumbents' facilities by new entrants and the needs to facilitate entry to the broadband market. This theory starts with the principles of interconnection and access pricing (Armstrong, 2002). According to this theory, the NRAs are responsible for facilitating the entry of new players to the broadband market when they are not able to develop their own infrastructure. They also have to regulate the access prices so that new entrants can afford the provision of the service. The entrant operator would therefore go through different phases ("rungs") in the access process, the first step being *bitstream,* followed by direct access (LLU), until a sufficient base of customers allowing the operator (if necessary) to deploy its own network has been reached. The LOI theory is presented as a way of introducing intra-platform competition in the broadband market when the incumbent lends the use of copper lines to new entrants; compared to the situation where the entrant competes with other players using its own network (inter-platform competition).

A great number of papers have empirically tested the LOI theory. Some of these studies found scenarios where the LOI theory might not have been effective. Denni and Gruber (2005) and Distaso et al. (2006) study the effects of intra-platform and inter-platform competition through panel data analysis in the US and Europe respectively, and find that in the long term inter-

---

[15] The LOI theory was proposed for first time by Martin Cave in 2001 in a report to the European Commission. The concept of LOI is detailed in "Encouraging infrastructure competition via the ladder of investment" (Cave, 2006). Ideas about the LOI theory were also developed in previous papers by Cave and Prosperetti (2001), and Cave and Volgensang (2003). Later, Cave (2010) and Cave (2014) also extend the LOI theory to NGANs.

platform competition has a stronger effect on penetration than intra-platform competition. The findings of Aron and Burnstein (2003) are along the same lines, and using US state data in 2000 found that inter-platform competition and cost elements are the drivers of broadband adoption. Haussman and Sidak (2005) make an empirical revision of the LOI theory, and more specifically the experiences of five countries with LLU. They don't find any stylised fact that supports the LOI theory approach. A study by Crandall and Sidak (2007) empirically examines the LOI experience in the EU, and finds that there was not a transition from resale/*bitstream* to LLU, in fact, incumbents' investment in new infrastructures is lower for countries that strongly promote mandatory access. Additionally, Hazlett and Bazelon's (2005) find that the LOI theory did not work for broadband nor for the local telephony market in the period 1999 to 2004 in the US. Wallsten (2006) constructs a panel dataset across 30 countries using two sources, the OECD and ITU, and fails to conclude if LLU or *bitstream* have stimulated broadband penetration, but finds a robust and negative effect on penetration growth due to "subloop unbundling" which is the most extensive form of mandatory unbundling (the entrants access is even further from the local exchange than when using *bitstream*). Finally, Hoffler (2007) uses data from 16 western European countries from 2000-2004, and concludes that competition between DSL and cable TV had a significant impact on broadband penetration. However, this author highlights inefficiencies due to the duplication of existing platforms.

In an advanced development phase of the broadband market, more recent papers have also tested the LOI theory using rich panel datasets, and the results are still mixed. Bouckaert et al. (2010) conclude that inter-platform competition (between DSL, cable modem and fibre) is the main driver of fixed broadband penetration. They use a panel dataset of 20 OECD countries from the period 2003 to 2008 to estimate the effect of regulation and competition on the size of penetration levels. The study of Pereira and Ribeiro (2010) focuses on the case of competition between DSL and cable operators in Portugal. They find that inter-platform competition increases the diffusion of broadband. Alternatively, Gruber and Koutroumpis (2013) find that inter-platform competition does not stimulate broadband adoption, and that markets using a single technology more intensively present higher penetration levels. Bacache et al. (2013) analyse a dataset of 15 EU countries over the period 2002 to 2010, and find only weak evidence to support the transition from *bitstream* to LLU, rejecting the hypothesis of migration from LLU to the deployment of a new network by the entrant. This is in line with the paper of Bourreau et al. (2010), which presents a critique of the LOI theory and suggests that the main problem with the LOI theory is that once entrants obtain some profits with *bitstream* access, their incentives to invest further might not be high, creating a "replacement effect". More recently, Nardotto et al. (2014) use data for the UK over the period 2005 to 2010 and find that LLU had little or no effect on broadband penetration. Interestingly however, they obtain that LLU increased quality in terms of higher download speeds. On the other hand, they demonstrate that inter-platform competition from cable modem increased local broadband penetration

The regulation of NGANs and the debate about the incumbents' interest in deploying fibre networks under access regulation, combined with entrants' incentives to invest in their own networks, has also inspired a lot of research. The empirical paper on the effects of access regulation on NGANs' investment, developed by Wallsten and Hausladen (2009), uses a dataset of 27 EU countries from 2002 to 2007. The result of their analysis is that the higher the use of LLU or *bitstream*, the lower the frequency fibre penetration. However, inter-platform competition between DSL and cable modem has a positive impact on the number of fibre connections. In their empirical study, Grajek and Roller (2012) show the effect that access regulation had on operators' incentives to invest using a panel dataset of 20 countries for the period 1997 to 2006. According to their findings, both the incumbents and entrants have been discouraged by regulation, suggesting that the European regulatory framework has not been able to promote facility-based competition. These authors conclude that when incumbents have invested in new networks, the regulators have toughened access regulation while not changing the access price policies in line with entrants' investments. Finally, Briglauer et al. (2013) apply panel data estimation techniques to a sample of 27 EU countries from 2005 to 2011 and, interestingly, find that the investment in fibre technologies has been lower if regulatory policies have been effective in promoting the use of *bitstream* amongst entrants. They also find that cable modem and wireless technologies have had a non-linear impact on the deployment of NGANs, a pattern which follows a "U-shape".

A few studies have also analysed how the level of access price-levels set by NRAs might produce different outcome on the effectiveness of the LOI theory. In an early revision of the literature, Valletti (2003) signals that there is not a clear relationship between access prices and investment incentives. Also, Crandall et al. (2004) do not find that lower UNE (Unbundling Network Element) rates stimulate future facility-based investment in the US. On the contrary, Waverman et al. (2007) model the effect of LLU prices and find that a 10 percent reduction in LLU prices results in an 18% reduction in subscribers to alternative infrastructures. Along the same lines, Willig (2006) finds that a decrease in the price of LLU encourages both competition and investment. Lastly, Inderst and Peitz's (2012) theoretical model finds that a higher access charge would reduce the investment incentives of the incumbent, whilst increasing those of the entrant.

Overall, these studies show us that the LOI theory seems not to have performed as many might have wished when the theory was first conceived. In fact, many of these studies point out that inter-platform competition stimulates broadband adoption, whilst intra-platform competition does not. Moreover, all papers in the literature review seem to find a negative effect on investment in new networks in countries that have used the LOI approach. However, those papers which use more recent and longer series of data seem to find some (slight) evidence of a transition from *bitstream* to LLU, or at least an improvement in the quality delivered by broadband services with the use of LLU compared to *bitstream* (Nardotto et al., 2014).

4.3. Studies on the diffusion of the mobile broadband

A group of empirical papers have analysed the evolution of the mobile voice service over recent decades. Some papers, such as Gruber and Verboven (2001), use the logistic diffusion model to analyse the evolution of cellular mobile services from 1981 to 1997 all over the world. These authors found that standardisation policies in the analogue phase (1G technology) had a positive effect on mobile penetration, but the subsequent standardisation of digital technologies (2G) in the EU might not have had a significant impact on the diffusion of the service. Similarly, Liikanen et al. (2004) analysed the impact of first and second generation mobile technology in a group of 80 countries over the period 1992-98. They showed that the level of penetration of 1G technology positively affected the expansion of 2G technology, meaning that the substitution effect between technologies dominated the network effect. It seems that this effect has also been important in the transition from 2G, to 2.5G, and to 3G. Therefore, in the case of mobile telephony the compatibility among technologies has avoided a lock-in effect. More recently, Bohlin et al. (2010) have analysed the factors determining the diffusion of mobile telephony in a group of 177 countries over the period 1990-2007. They show that the expansion of 2G and the 3G technologies has been strongly influenced by the level of urbanisation in the countries in question, as well as the GDP per capita, the penetration of fixed broadband Internet, and the regulation of the market. They also explain that 1G technology promoted the subsequent development of 2G, but that this standard has had a negative impact in the expansion of 3G. This suggests that 2G and 3G were competing for a common customer base. The level of competition in the market appears as a key factor in the speed of diffusion of one technology standard, but this effect was less important during the transition from 2G to 3G technology. Regarding the latter, the same authors argue that the capability of 2G technologies to provide data transmissions made it less necessary for customers to switch to 3G networks. This result could also be related to the higher saturation of the mobile market around the year 2000 when 3G was launched, compared to the beginning of the 1990'a when 2G technology was first offered.

The mobile broadband service appeared more recently, therefore literature is still sparse compared to the available studies on fixed broadband. An exception is the study by Lee et al. (2011) who find that the main drivers for fixed broadband in OECD countries are LLU, income, population density, education and prices. These authors also analyse mobile broadband diffusion from 2003 to 2008, showing that multiple standardisation policies and population density significantly affect the diffusion of mobile broadband services. Moreover, they examine jointly the drivers of fixed and mobile broadband, and their results suggest that in many OECD countries mobile broadband is a complement to fixed broadband. Srinuan et al. (2012) uses survey data for 2010 in Thailand and finds that price, availability of fixed telephony, and age exhibit a positive and significant effect on mobile Internet adoption, as well as area of living and the characteristic of the mobile operator are important factors. This study also shows that mobile broadband is useful in reducing the "digital divide", as some consumers prefer to use mobile broadband instead of fixed broadband. Haucap et al. (2014) analysed the effect of tariff diversity on broadband uptake rates using a dataset of fixed broadband plans and mobile broadband plans via USB modem devices. They find that mobile broadband prices do not affect the level of fixed broadband penetration, and that the main drivers of the adoption of fixed broadband services are their prices, income, and tariff diversity.

Studies on mobile broadband diffusion usually include the analysis of fixed broadband, or investigate the substitution patterns between both services. Contrary to fixed broadband, where there are many studies that test the LOI theory, studies on mobile broadband are more diverse. Nonetheless, many of the papers on mobile broadband cover the effects of the technological evolution and the implementation of standards, which point out the network effects advantages for countries which adopted a common standard during the analog phase (1G). However, the transition and release of several digital standards (2G and 3G technologies) seems to be less important in the diffusion of the service. This is probably because the possibilities of compatibility, as well as the similar features offered by 2G and 3G digital standards, might have been reflected in lower penetration growth rates of 3G.

4.4. Pricing policies in the retail broadband sector

So far, very few papers have analysed the price setting mechanisms of broadband services. Wallsten and Riso (2010) describe and analyse a data set of 25,000 residential and business broadband plans from 30 OECD countries between 2007 and 2009. The first result of their analysis is that plans which were capped in volume were cheaper than unlimited plans, unless the customer consumes additional gigabytes above the cap. Second, the authors found that residential prices in the US were stable compared to a general decline in the rest of the countries looked at over the study period. Although average retail prices remained constant in the US, for business plans the high speed tiers presented price reductions. They also found that plans with contracts are less expensive than plans without them. Another study by Wallsten and Mallahan (2010) uses data from the FCC, combined with other sources to test the effects of competition on speeds, penetration, and prices in the US. Their econometric analysis shows that the presence of a high number of fixed broadband providers has a positive effect on transmission speeds and reduces prices. However, they also highlight that the dataset they use might show some inconsistencies since it does not include bundled plans or promotions.

Greenstein and McDevitt (2011) analyse the evolution of fixed broadband prices in the US during the period 2004 to 2009. The authors construct diverse price indexes (Laspeyres, Paasche and Fisher) using the tariffs of 1,500 plans. This shows that broadband prices fell slightly during this period for stand-alone plans, but prices remained relatively constant for bundles including broadband. These authors conclude that prices for broadband plans declined modestly, around three to ten percent, during the study period.

The descriptive paper by Galperin (2012) highlights the high price elasticity for the demand of the fixed broadband service; and hence the relevance of reducing prices. They find that broadband prices in Latin America, in comparison with OECD countries, are above the threshold which would allow for saturation of the broadband market.

Related to pricing policies in the mobile sector, Srinuan et al. (2013) analyse in detail how operators release "innovative plans"[16] which exploit consumer heterogeneity, reflect demand needs, and attract and retain subscribers in the Thai mobile market between 2002 and 2010. They find that a greater number of price plans can increase competition among operators, but that complex tariffs might also be confusing. This means customers might end up paying more than they actually need to. Finally, they also find that big operators introduce more innovative tariff plans than small operators.

5. Main contributions of the thesis

This dissertation will shed light on how fixed and mobile operators commercialise their broadband plans. It will also demonstrate the effects of the market structure and regulation of wholesale access on the prices paid by consumers. The common thread throughout the three main chapters of the dissertation is an analysis of the hedonic factors that differentiate broadband plans and explain differences in prices. The methodology is based on the application of econometric techniques on two rich panel datasets of fixed and mobile broadband plans. Aside from the basic characteristics of the

[16] Corrocher and Zirulia (2010) define "innovative plans" as a new tariff plan. These authors also identified several characteristics of a price plan: pre-paid versus post-paid plans, subscription fees, price per unit, time-base charges, on-net versus off-net call, rebates and promotions, bundling, etc.

broadband service, the second and third chapters study the impact of competition and regulation factors on the prices in equilibrium. The dissertation applies ordinary least squares (OLS) and also two stage least squares (2SLS) to mitigate the endogeneity problems associated with the penetration of the broadband service.

Chapter 2: "Broadband prices in the European Union: Competition and commercial strategies"

This chapter examines the factors that have determined the prices of fixed broadband plans in 15 EU countries during the period 2008-2011. First, it shows that download speed and bundling are key factors in the level of prices. The analysis also shows that, for plans offering the same download speed, fibre and cable broadband prices are similar to DSL. Incumbent operators charge greater prices than entrants, and customer segmentation also leads to higher prices. The most important contribution made by this paper is to identify the effect of competition and regulation on prices. Specifically, the study shows that prices are higher in markets where entrants exhibit a high usage of *bitstream* access, and are lower in the markets where entrants make intensive use of direct access (LLU). In spite of this, inter-platform competition (between DSL, cable modem and fibre platforms) does not have a strong impact on prices.

I believe the results regarding the regulated access to the incumbent's network might be useful to NRAs when they set the levels of access prices paid by entrants to provide the broadband service, as the convenience of promoting some facility-based entry policies as a mechanism to obtain larger price reductions for end consumers is demonstrated. In this sense, the recent work of Bacache et al. (2011) for 15 EU countries shows that the ladder of investment approach may facilitate migration from the use of *bitstream* access lines to local loop unbundling (LLU).

Chapter 3: "Pricing strategies and competition in the mobile broadband market"

This study analyses in depth the pricing strategies used by mobile operators to set prices for mobile broadband plans on smartphone. This chapter uses a similar approach to Chapter 2 for a dataset of mobile broadband plans on smartphone from 2011 to 2014 all over the world (37 countries in total). The research reveals that multi-tier pricing is a common strategy across operators who usually set volume limits for Internet usage (data caps) as well as voice services (minutes caps), and who apply different types of penalties after the customer has exhausted the initial data included with the tariff. These penalties might imply a drastic reduction in the download speed (only a few operators stop the service completely) or a monetary penalisation (a new volume allowance or pay per unit of consumption, pay-as-you-go). Hence, the monthly price also depends on the type of penalty included in the plan. On the other hand, unlimited data plans are much less common, and are more expensive.

Bundling is also a very relevant aspect of mobile plans; apart from including allowances of voice minutes and Internet in the same offer, operators also bundle mobile broadband plans with diverse types of smartphones and embed the cost of handsets in the monthly price, tying customers for a longer period of time (i.e. longer contract duration). One of the most insightful results of this chapter reveals that some plans offering branded handsets result in substantially more expensive tariffs than stand-alone (SIM-only) offers, although some brands might not embed additional fees.

This study presents a discussion about how operators might use multi-tier pricing to maximise the benefits inherent in commercialising mobile Internet services; as well as their incentives of selling the mobile plan with the smartphone. Indeed, the results found on these two topics are linked to recent research on Internet data caps (Economides et al., 2015) and exclusive contracts between mobile operators and handset manufacturers (Sinkinson, 2014).

Finally, examining a group of 20 EU countries, this chapter assesses the effects of market structure and regulation of entry on the level of prices. It is shown that mobile operators' concentration in these 20 countries does not have a significant impact on prices. Also, the regulation of termination prices (MTRs) that mobile operators charge to their rivals for terminating their telephone calls does not appear to affect the level of prices either. Only the entry of MVNOs seems to reduce prices slightly, which suggests that there is room for more competition in this market.

Chapter 4: "Competition in the Spanish mobile broadband market"

The fourth and final chapter of the dissertation focuses on the Spanish case, and studies the mobile broadband service in this country, from the start of the liberalisation process at the end of the 1990s to December 2014. First, this study describes the process of technological innovation that has facilitated the emergence of mobile broadband and the launch of this service in Spain. Also, it illustrates how the market restructuring experienced in the Spanish mobile sector since the end of the 1990s has evolved to a less concentrated market and more competition.

The analysis shows the high level of competition and penetration in the Spanish market compared to the rest of the communications services. Nevertheless, the comparison of the Spanish mobile market with other European countries demonstrates that the high rates of mobile broadband penetration in Spain cannot be reconciled with the presence of higher prices than in many other European countries. With respect to prices, MVNOs seem to be pro-competitive, and some concerns arise about the need to facilitate MVNOs reaching new agreements with MNOs for the use of 4G technologies. Also, fixed-mobile bundles (four and five play bundles) have been well-adopted by Spanish consumers due to associated discounts, and also because Spanish consumers are keen to pay for all of their communications services in a single bill. Overall, communications plans and tariffs in the Spanish market evolve rapidly, and to some extent, have had an impact on the market structure and new acquisitions which occurred within the Spanish telecoms market during 2014.

References

Alabau, A. and Guijarro, L., 2011. "The Electronic Communications Policy of the European Union", Universitat Politécnica de València.

Amichai-Hamburger, Y., and Hayat, Z., 2013. "Personality and the internet". In Y. Amichai-Hamburger (Ed.), The social net: Understanding our online behavior,. 1–20. New York: *Oxford University Press.*

Armstrong, M., 2002. "The theory of access pricing and interconnection", *Handbook of Telecommunications Economics*, Vol. I, Elsevier: Amsterdam, 297-384.

Aron D.J. and Burnstein, D., 2003. "Broadband adoption in the United States: an empirical analysis", Shampine, A.L. (Ed.), Down to the Wire: Studies in the Diffusion and Regulation of Telecommunications Technologies, *Nova Science Publishers*, Haupaugge, NY, 119-38.

Bacache, M., Bourreaum M., and Gaudin, G., 2014. "Dynamic Entry and Investment in New Infrastructures: Empirical Evidence from the Fixed Broadband Industry", *Review of Industrial Organisations, forthcoming*, 44 (1), 179-209.

Benhabib, J, and Spiegel, M., 2005. "Chapter 13 Human Capital and Technology Diffusion", *Handbook of Economic Growth,* Volume 1, Part A, 2005, 935–966.

Bohlin E., Gruber, H., and Koutroumpis, P., 2010. "Diffusion of new technology generations in mobile communications", *Information Economics and Policy,* 22(1), 51-60.

Bouckaert, J., Van Dijk, T., and Verboven, F., 2010. "Access regulation, competition, and broadband penetration: An international study", *Telecommunications Policy*, 34, 661-671.

Bourreau, M., Dögan, P., and Manant, M., 2010. "A critical review of the ladder of investment approach", *Telecommunications Policy*, 34 (11), 683-696.

Briglauer, W., Ecker. G., and Gugler, K., 2013. "The impact of infrastructure and service-based competition on the development of next generation access networks: recent evidence from the European member states", *Information Economics and Policy*, 25, 142-153.

Calzada, J. and Costas, A., 2014. "La liberalización de las telecomunicaciones en España: Objetivos europeos versus intereses nacionales", *Revista de Historia Industrial* (forthcoming).

Calzada, J. and Estruch, A., 2013. “Comunicaciones Móviles en la Unión Europea: tecnología, políticas y mercado”, *Papeles de Economía Española*, N.º 136

Calzada, J. and Martínez-Santos, F., 2014a. “Broadband prices in the European Union: Competition and commercial strategies”, *Information Economics and Policy*, 7, 24–38.

Calzada, J. and Martínez-Santos, F., 2014b. “Competencia en el Mercado de banda ancha móvil en España”, *Cuadernos Económicos del ICE*, 88, 97-129.

Calzada, J. and Trillas, F., 2006. “Los precios de precios de interconexión en las telecomunicaciones: de la teoría a la práctica”, *Hacienda Pública Española*, Vol. 173, 2, 85-125.

Cambini, C. and Jiang, Y., 2009. “Broadband Investment and Regulation: A literature Review,” *Telecommunications Policy*, 33 (10-11), 559-574.

Cava, I. and Alabau A., 2006. “Broadband policy assessment: a cross national empirical analysis”, *Telecommunications Policy*, 30, 445-463.

Cave, M. and Prosperetti, L., 2001. “European Communications Networks”, *Oxford Review of Economic Policy*, no 3, 2001.

Cave, M. and Vogelsang, I., 2003. “How access pricing and entry interact”, *Telecommunications Policy* 27, 717-727.

Cisco, 2015. “Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014–2019”.

CMT, 2013a. Informe Económico Sectorial 2012. Comisión del Mercado de las Telecomunicaciones.

CMT, 2013b. “Estrategias de venta de terminales y precio de los servicios móviles”, Nota ocasional 7.

CNMC, 2014a. “Efecto arrastre entre las demandas de servicios fijos y de servicios móviles tras la eclosión en España de los paquetes convergentes de servicios fijos y móviles", Documento de Trabajo número 2, Abril 2014.

CNMC, 2014b. "Cambios de operadores de los servicios de comunicaciones electrónicas en el sector residencial en 2013", Documento de Trabajo nº 3, Julio 2014.

CNMC, 2014c. "Informe de seguimiento de las ofertas comerciales de servicios de comunicaciones móviles entre 2012 y 2013", Documento de Trabajo nº 12, Julio 2014.

CNMC, 2014d. "Informe Económico de las Telecomunicaciones y del Sector Audiovisual 2014", Comisión Nacional de los Mercados y de la Competencia.

Corrocher, N. and Zirulia, L., 2010. "Demand and innovation in services: The case of mobile communications", *Research Policy*, Elsevier, Vol. 39(7), 945-955.

Crandall, R., Ingraham, T., and Singer, H.J., 2004. "Do Unbundling Policies Discourage CLEC Facilities-Based Investment", *The B.E. Journals in Economic Analysis and Policy*, 4(1).

Crandall, R., Lehr, W., and Litan, R., 2007. "The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data", *Issues in Economic Policy*, The Brookings Institution, No. 6, July.

Crandall, R., and Sidak, J.G., 2007. "Is Mandatory Unbundling the Key to Increasing Broadband Penetration in Mexico? A Survey of International Evidence".

Crandall, R., Sidak, J.G. and Singer, H.J., 2002. "The empirical case against the regulation of broadband access", *Berkeley Technology Law Journal*, Vol. 17 No. 3, 953-87.

Crawford, G. and Yurukoglu, A., 2012. "The Welfare Effects of Bundling in Multichannel Television Markets", *American Economic Review*, 102(2), 643-85.

Czernich, N., Falck, O., Kretschmer, T. and Woessmann, L., 2011. "Broadband Infrastructure and Economic Growth", *The Economic Journal*, 121 (May), 505-532.

Denni, M. and Gruber, H., 2005. "The Diffusion of Broadband Telecommunications: The Role of Competition" Italian Competition Authority; University of Rome III - Department of Economics, September 2005, Working Paper n° 60, 2006.

Distaso, W., Lupi, P. and Manenti, G., 2006. "Platform Competition and Broadband Uptake: Theory and Empirical Evidence", *Information Economics and Policy*, 18 (1), 87-106.

Divya, Kumar, A., Liu., Y., and Sengupta, J., 2010. "Evolution of Mobile Wireless Communication Networks: 1G to 4G", *International J. of Elect. and Comm.* Tech 1 (1), 68-72.

Economides, N. and Hermalin, B.E., 2015. "The Strategic Use of Download Limits by a Monopoly Platform", forthcoming in *Rand Journal of Economics*, 46, 2, 297-327.

European Commission, 2002. Directive 2002/21/EC of the European Parliament and of the Council.

European Commission, 2003. Commission Recommendation 2003/311/EC.

European Commission, 2007. Commission Recommendation of 17 December 2007. Official Journal L 344 of 28.12.2007.

European Commission, 2009a. "15th Progress Report on the Single European Electronic Communications Market – 2009".

European Commission, 2009b. Regulation (EC) No 1211/2009.

European Commission, 2011. "Broadband Internet Access Costs (BIAC)". Final Report, Information Society and Media Directorate-General.Van Dijk – Management Consulting.

European Commission, 2012a. "Digital Agenda for Europe, Scoreboard 2012". Directorate-General for Communication Networks, Content and Technology (DG-CONNECT), Brussels.

European Commission, 2012b. "Broadband Internet Access Costs (BIAC)". Final Report, Information Society and Media Directorate-General.Van Dijk – Management Consulting.

European Commission, 2012c. E-communications Households Survey. Report. Special Eurobarometer 381. Directorate-General for Information Society and Media, Brussels.

European Commission, 2013a. "The mobile use of the Internet by individuals and enterprises". *Digital Agenda Scoreboard 2013*, Chapter 4, June 2013.

European Commission, 2013b. Broadband Internet Access Costs (BIAC). Final Report, Information Society and Media Directorate-General. Van Dijk – Management Consulting.

European Commission, 2014. E-Communications and Telecoms Single Market Household Survey, *Special Eurobarometer*, No. 414, Brussels.

Evans, D. and Salinger, M., 2005. "Why do firms bundle and tie? Evidence from competitive markets and implications for tying law", *Yale Journal on Regulation*, 22, 37-89.

FCC, 2015. "Fourth International Broadband Data Report", Federal Communications Commission, Washington.

Fornefeld, M., Delaunay, G., Elixmann, D., 2010. "The Impact of Broadband on Growth and Productivity", A study on behalf of the European Commission. Düsseldorf: MICUS.

Galperin, H., 2012. "Prices and quality of broadband in Latin America: Benchmarking and trends", *Economics of Networks eJournal* 4(64).

Gillett, S., Lehr, W., and Osorio, C., and Sirbu, M. A., 2006. "Measuring Broadband's Economic Impact", Technical Report 99-07-13829, National Technical Assistance, Training, Research, and Evaluation Project.

Grajek, M., and Röller, L-H., 2012. "Regulation and investment in network industries: Evidence from European telecoms", *Journal of Law and Economics*, 55 (1): 189-216.

Greenstein, S. and McDevitt, R., 2011a. "The Broadband Bonus: Estimating broadband Internet's economic value", *Telecommunications Policy*, 35 (7), 617-632.

Greenstein, S. and McDevitt, R., 2011b. "Evidence of a modest price decline in US broadband services", *Information, Economics and Policy*, 23 (2), 200-211.

Griliches, Z., 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change" *Econometrica* Vol. 25 (October).

Gruber, H., 2007. "3G mobile telecommunications licenses in Europe: a critical review", *Info*, Vol. 9, n.6, 2007, 35-44.

Gruber, H., 2008. "The Economics of Mobile Communications", Cambridge, *Cambridge University Press*.

Gruber, H., and Koutroumpis, P., 2013. "Competition enhancing regulation and diffusion of innovation: the case of broadband networks", *Journal of Regulatory Economics*, 43: 168-195.

Gruber, H. and Verboven, F., 2001. "The evolution of markets under entry and standards regulation - the case of global mobile telecommunications", *International Journal of Industrial Organisations*, Elsevier, Vol. 19(7), 1189-1212, July.

Haucap, J, Heimeshoff, U., and Lange, M., 2014. "The Impact of Tariff Diversity on Broadband Diffusion – An Empirical Analysis", Düsseldorf Institute for Competition Economics, Discussion Paper 156.

Hausman, J. and Sidak, G., 2005. "Did mandatory unbundling achieve its purpose? Empirical evidence from five countries", *Journal of Competition Law and Economics*, 1, 173-245.

Hazlett, T. and Bazelon, C., 2005. "Regulated Unbundling of Telecommunications Networks: A Spetting Stone to Facilities-Based Competition", mimeo.

Höffler, F., 2007. "Cost and benefits from infrastructure competition. Estimating welfare effects from broadband access competition", *Telecommunications Policy, 31*(6-7), 401-418.

Hovenkamp, H., 2008a. "The Antitrust Enterprise, Principle and Execution", *Harvard University Press*, United States.

Hovenkamp, H., 2008b. "Unilateral refusals to deal, vertical integration, and the essential facility doctrine (July 1, 2008)", U. Iowa legal studies research paper No. 08-31.

Inderst, R. and Peitz, M., 2012. "Informing consumers about their own preferences", *International Journal of Industrial Organisations*, Elsevier, Vol. 30(5), 417-428.

ITU, 1999. "World Telecommunication Development Report, Mobile Cellular".

ITU, 2003a. "Collection of the basic texts of the International Telecommunication Union adopted by the plenipotentiary conference", edition 2003.

ITU, 2014. "Measuring the Information Society Report 2014".

ITU & UNESCO, 2014. "Broadband Commission for Digital Development".

Katz, R. and Suter, S., 2009. "Estimating the economic impact of the broadband stimulus plan", Columbia Institute for Tele-Information Working Paper.

Kehoe, J., Kim, J., 2009. "Sudden Stops, Sectoral Reallocations, and the Real Exchange Rate", *Journal of Development Economics*, 2009, 89(2), 235-249.

Kiiski, A., 2006. "Impacts Of MVNOs on Mobile Data Service Market". 17th

European Regional ITS Conference.

Kimiloglu, H., Ozturan, M., Kutlu, B., 2011. "Market Analysis for Mobile Virtual Network Operators (MVNOs): The Case of Turkey", *International Journal of Business and Management*, Vol: 6, No. 6, 39-54.

Kleinrock, L., 2005. "A Vision for the Internet," *ST Journal for Research*, Vol. 2, no. 1, 4–5.

Koutroumpis, P., 2009. "The economic impact of broadband on growth: A simultaneous approach", *Telecommunications Policy,* 2009, Vol. 33, issue 9, 471-485.

Kraut, R., Mukhopadhyay, T., Szczypula, S., Kiesler, S., and Scherlis, W., 1998. "Communication and information: Alternative uses of the Internet in households", In Proceedings of the CHI 98, 368-383. New York: ACM.

Lee, S., Marcu, M. and Lee, S., 2011. "An Empirical analysis of fixed and mobile broadband diffusion", *Information Economics and Policy*, 23, 227-233.

Leider, S. and Sahin, O., 2015. Contracts, biases and consumption of access services, mimeo.

Leiner, B.M., Cerf, V.G., Clark, D.D., Kahn, R.E., Kleinrock, L., Lynch, D.C., Postel, J., Roberts L.G., Wolff S., 2003. "A Brief History of the Internet", *Internet Society.*

Liikanen, J., Stoneman, P. and Toivanen, O., 2004. "Intergenerational effects in the difussion of new technology: the case of mobile phone", *International Journal of Industrial Organisations*, 22 (8-9), 1137-1154.

McDevitt, Ryan C., 2011. "Names and Reputations: An Empirical Analysis", *American Economic Journal: Microeconomics*, 3 (3), 193-209.

Nakamura, A., 2015. "Mobile and fixed broadband access services substitution in Japan considering new broadband features", *Telecommunications Policy,* Volume 39, Issue 2, 93-158.

Nardotto, M., Valletti, T. and Verboven, F., 2014. "Unbundling the Incumbent: Evidence from UK broadband," CEIS Research Paper 331, Tor Vergata University, CEIS.

Nelson R. and Phelps E., 1996. "Investment in Humans, Technological diffusion and Economic Growth", *American Economic Review*. May 56 (2).

OECD, 2008. "Broadband Growth and Policies in OECD Countries". OECD Ministerial Meeting on the Future of the Internet Economy.

OECD, 2014. "The Development of Fixed Broadband Networks", OECD Digital Economy Papers, No. 239, *OECD Publishing*. http://dx.doi.org/10.1787/5jz2m5mlb1q2-en.

OECD, 2015. "Broadband subscriptions per 100 inhabitants in OECD countries", Last updated February 2015. OECD Broadband Portal.

Papacharissi, Z., and Zaks, A., 2006. "Is Broadband the Future? An Analysis of Broadband Diffusion and Potential and diffusion", *Telecommunications Policy,* 30, 64-75.

Pereira, P. and Ribeiro, T., 2010. "The impact on broadband access to the Internet of the dual ownership of telephone and cable networks", *International Journal of Industrial Organisations,* 29, 283–293.

Rajani, M. K., & Chandio, M. S., 2004. "Use of Internet and its effects on our Society", Proceedings of the National Conference on Emerging Technologies (NCET), December 18-19, 2004 157-161.

Renda, A., 2010. "Competition–regulation interface in telecommunications: What's left of the essential facility doctrine", *Telecommunications Policy* 34 (1), 23-35.

Rickford, J., 1998. "Change, politics and determinist economics in Europe", *Telecommunications Policy,* Vol. 22, 471-82.

Roller, LH., and Waverman, L., 2001. "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach", *American Economic*

Review, 91(4): 909-923.

Sinkinson, M., 2014. "Pricing and Entry Incentives with Exclusive Contracts: Evidence from Smartphones", mimeo.

Srinuan, P., Bohlin, E., and Madden, G., 2012. "The determinants of mobile subscriber retention in Sweden". *Applied Economics Letters,* 19(5), 453 – 457.

Srinuan, C., Srinuan, P., and Bohlin, E., 2012. "An analysis of mobile Internet access in Thailand: Implications for bridging the digital divide", *Telematics and Informatics 29(3),* 254-262.

Srinuan, C., Srinuan, P., and Bohlin, E., 2013. "Pricing strategies and innovations in the Thai mobile communications market", *Info*, 15 (1) , 61 – 77.

Stigler, George J., 1971. "The theory of economic regulation", *Bell Journal of Economics and Management Science*, Vol. 2, Issue 1 (spring, 1971): 3-21.

Valletti, T., 2003. "Input price discrimination with downstream Cournot competitors", *International Journal of Industrial Organisations*, Elsevier, Vol. 21(7), 969-988.

Vogelsang, I., 2003. "Price Regulation of access to telecommunications networks", *Journal of Economic Literature*, 41 (3).

Vogelsang, I., 2010. "The Relationship between mobile and fixed-line communications: a survey", *Information Economics and Policy*, 22(1): 4-17.

Wallsten, S., 2006. "Broadband and Unbundling Regulations in OECD Countries", AEI-Brookings Joint Center for Regulatory Studies Working Paper.

Wallsten, S. and Hausladen, S., 2009. "Net Neutrality, Unbundling, and their Effects on International Investment in Next-Generation Networks", *Review of Network Economics* Vol.8, Issue 1 – March 2009.

Wallsten, S. and Riso J.L., 2010a. "Residential and Business Broadband Prices: Part 1: An Empirical Analysis of Metering and Other Price Determinants", Technology Policy Institute.

Wallsten, S. and Riso, J.L., 2010b. "Residential and Business Broadband Prices: Part 2: International comparisons", Technology Policy Institute.

Wallsten, C. and Mallahan, 2010. "Residential broadband competition in the United States", SSRN eLibrary.

Waverman, L., Leschi, M., Reillier, B., and Dasgupta, K., 2007. "Access regulation and Infrastructure Investment in the Telecommunications Sector: An empirical Investigation", mimeo.

Willig, R., 2006. "Investment is appropriately stimulated by TELRIC". Princeton University.

Chapter 2

Broadband prices in the European Union: competition and commercial strategies[17]

1. Introduction

Over the last decade, millions of people in the European Union have installed broadband in their households[18], thus enabling them to download information and to use sophisticated digital services.[19] Broadband Internet access is an essential component of inclusiveness in the 21st century, and households without broadband access are in risk of becoming marginalised from society and economic opportunity. Several papers have analysed the impact that technological change and regulation have had on the expansion of Internet. However, little attention has been given to how telecommunication operators adapt their pricing and commercial strategies to market evolution and competition. The analysis of the way in which prices are established is essential to orientate regulatory and competition policies in this sector. Moreover, it can help shed light on the significant price and quality differences across EU Member States.

Effective competition plays a key role in expanding broadband access and in ensuring that consumers benefit from lower prices, greater choice and better quality services. However, competition can be affected by several problems, including the lack of investment in new technologies, price discrimination, margin squeeze, or excessive pricing. Competition in the provision of retail broadband services also depends on effective competition at the wholesale level, or, if this does not exist, on its effective regulation. In Europe, telecommunications regulators conduct regular analyses in order to define the

---

[17] This chapter has been previously published as "Calzada, J. and Martínez-Santos, F., 2014. Broadband prices in the European Union: Competition and commercial strategies, *Information Economics and Policy*, 7, 24–38".

[18] The European Commission 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" (European Commission, 2009 and 2011b).

[19] During the nineties, broadband was delivered over cable and telephone lines. In the years that followed, these technologies were upgraded and some operators began to deploy fibre for home delivery as this would support a higher bandwidth.

relevant broadband market and to determine which firms have significant market power (SMP) and need to be regulated. In this context, price analysis is necessary to examine the conduct of operators and to assess the state of competition.

This paper analyses the factors that determined fixed broadband Internet prices in 15 EU Member States between 2008 and 2011.[20] We employ a rich data set that contains both the commercial and technical characteristics of 2204 plans offered to households by incumbent and entrant operators. By using an instrumental variable approach we estimate a pricing equation using three types of variables: (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 operators' commercial plans to examine the influence of competition and regulation on broadband retail prices.

We analyse 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. And second, we explain that cable modem and fibre (FTTx) broadband plans have lower prices per Mbps than xDSL plans. This is an interesting result that questions the interest that operators might have for deploying Next Generation Access Networks (NGAs).

We then examine the importance of several commercial practices typically adopted by operators. We show that flat rate plans are more expensive than metered plans (which limit the downloadable volume), and that plans that bundle broadband Internet access with voice telephony and/or television are also more expensive, especially in the case of triple packages. In the last year there has been an important debate in the literature and among practitioners concerning the motivations of operators' use of bundling. Our paper contributes to this debate by showing the effects of bundling on prices.

The paper also examines how competition and regulation affect operators'

[20] In spite of their growing relevance, mobile broadband services are not included in our analysis. Note that the commercial characteristics of mobile plans 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 fixed broadband).

pricing strategies. We show that incumbents set prices that are significantly higher than those of entrants, which might be a consequence of factors such as their wider coverage, reputation, or the incumbents' concerns about the price-squeeze tests set by competition authorities. Moreover, we obtain that the number of plans offered by each operator in a country has a positive effect on their prices. This result suggests that market segmentation and consumer confusion about the economic and technical characteristics of plans might allow firms to set higher prices.

Finally, the main contribution of the paper is to identify the effects of access regulation. We find that prices are higher in countries where entrants make a more intensive use of bitstream access, and lower when they rely more heavily on direct access (local loop unbundling, LLU). Despite this, we observe no significant effect on prices when entrant upgrades their own networks, nor do we find a robust effect of inter-platform competition between xDSL, cable and FTTx. These results might be interpreted as a consequence of the application of the "ladder of investment" approach (LOI), whereby in order to promote sector competition regulators initially facilitate the access of entrants to incumbents' network so as to guarantee service-based competition, and subsequently, once these entrants have acquired experience and reputation they create incentives to entrants to invest in their own infra-structure. The objective of this regulation is to reconcile the long-term benefits of facility-based competition with short-term price reductions. In spite of this, the effectiveness of this strategy has been questioned.[22]

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 also 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. Section 6 discusses the main contributions of the paper. Finally, Section 7 concludes.

[22] 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.

2. Literature review and the European broadband market

2.1. Review of the empirical literature on broadband access

The initial empirical literature on broadband Internet access focused on the determinants of its penetration. For example, Distaso et al. (2006) report the impact of inter-platform competition on broadband penetration in 14 European countries from 2000 to 2004. They find that while inter-platform competition had a positive effect on penetration, intra-platform competition did not play an important role. Other studies, including Höffler (2007), have highlighted the inefficiencies created by the duplication of existing platforms.[23]

More recent papers have analysed the impact of the regulation of wholesale prices on the investment decisions of firms and on the diffusion of the service.[24] Grajek and Röller (2012) examine the effects of access regulation on incentives for investment in 20 countries in the period 1997–2006. They explain that regulation has discouraged the investment of incumbents and individual entrants, and suggest that the European regulatory framework has failed to provide incentives for facility-based competition. They also examine the regulators' response to infrastructure investments, concluding that whereas access regulation has not been affected by the entrants' investments, regulators have toughened access regulation in response to increased investment by incumbents. Bouckaert et al (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 infra-structure-based operators (e.g. cable modem and FTTx); (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 shared lines); and (3) service-based intra-platform competition, where entrants resell the incumbent's services (bitstream

[23] There is a number of papers that have analysed the diffusion of broadband services. See for example Cava and Alabau (2006), Lee et al. (2011), Andrés et al. (2010) and Czernich et al. (2011).

[24] A detailed review of the theoretical literature on access charges in telecommunications can be found in Laffont and Tirole (2000), Armstrong (2002), and Vogelsang (2003).

access/resale). According to these authors, only infrastructure-based competition increases the penetration of the service, while the other types have little effect. Briglauer et al. (2013) examine the effects of infrastructure and service- based competition on the deployment of Next Generation Access (NGA) networks in a panel data set of the EU 27 Member States. They show that whereas infrastructure-based competition affects NGA deployment in an inverted U-shaped manner, service-based competition negatively affects total NGA investment of both incumbent and entrant operators.

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 et al. (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, using a data set of 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. This finding can be justified by the fact that full retail unbundling does not require duplication of networks, which reduces costs and, ultimately, prices.

The analysis of broadband prices has received much less attention.[25] 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. One major exception is the study conducted by Wallsten and Riso (2010), which examines broadband prices in a group of 30 OECD countries between 2007 and 2009. They find that downstream speed

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

has a positive effect on prices in the study period; that broadband plans with bit caps are on average offered at lower prices than unlimited plans; and that plans with contracts are typically less expensive than those without. While our paper confirms some of these findings, here, additionally, we examine the effect on the prices of competition and the impact of alternative entry patterns (bitstream, direct access and own networks).

Greenstein and McDevitt (2011) also analyse the economic value created by the diffusion of broadband Internet access provided via xDSL and cable in the United States. They do not have direct information on prices, but create a price index that adjusts prices 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. They explain that this is a very 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 EU Member States was 27.2%.[26] However, there were significant differences across countries. 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 (Fig. 1).[27]

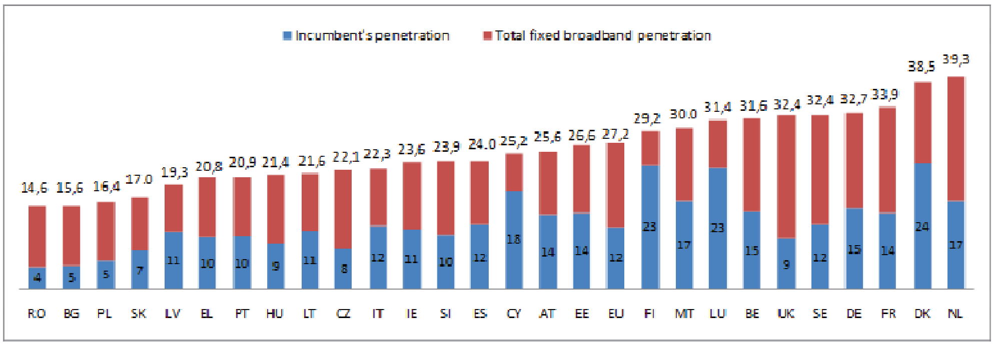
In recent years, the prices of fixed broadband Internet access have fallen significantly, which is quite remarkable if we consider that operators have improved the quality of their offers. Often operators allow consumers to migrate at no cost to other offers providing higher download speeds. Moreover, many offers bundle broadband access with other services such as fixed voice, TV, and more recently with mobile telephony. Such packages allow operators to attract new consumers (the bundle being cheaper than the

[26] As of the same date, the penetration of large screen mobile broadband subscriptions (using dedicated data cards or USB modems) was 7.5%.
[27] See the European Commission Implementation Reports (European Commission 2011a, b).

sum of the single services) and to gain the loyalty of their subscribers.

This situation has not prevented significant price differences across European countries (Fig. 2).[28] Price differences can be explained by the technical and commercial characteristics of the plans, but they might also reflect differences in the level of competition in national markets. Thus, while in 2011 the incumbent's market shares (according to the number of broadband lines) in Cyprus, Luxemburg and Austria were 73%, 72% and 55% respectively, in the UK and Bulgaria they were 29% and in Romania just 30%. Many EU countries have four or five alternative operators, but other national markets are much more fragmented. For example, in Germany there are around 100 regional entrants, though the incumbent retains a 46% market share.

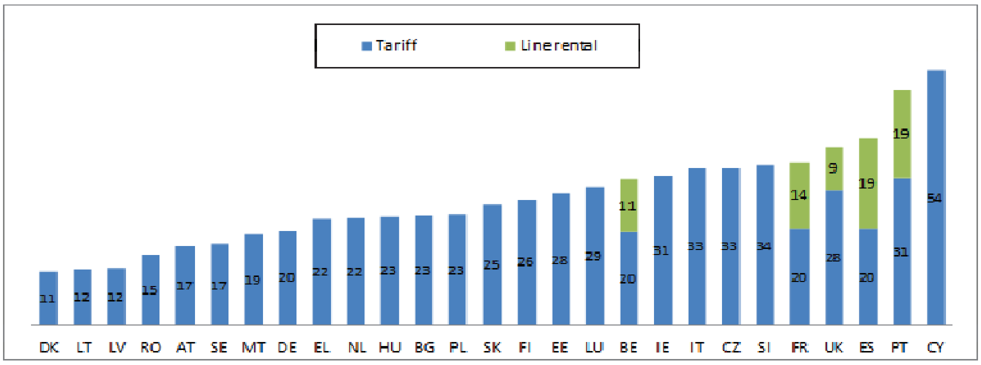
Figure 1: Fixed broadband and incumbent's penetrations in 2011 (%)



Source: European Commission (2011a).

[28] 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 occurs, for example, when wholesale access prices make it impossible for entrants to match the incumbent's prices.

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).

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 FTTx 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 than inter-platform competition.

Incumbent fixed telecommunications operators are usually vertically integrated (except in Sweden, the UK and Italy, where different types of vertical separation are found)[29] and use xDSL (although some use cable, which is the case, for example, of Denmark). 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 access charges in order to guarantee an adequate development of competition. There are two mandatory types of access. Entrants can access the incumbent's network directly (direct access or 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;

[29] For an analysis of vertical separation in telecommunications see for example Teppayayon and Bohlin (2010).

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 advantage of unbundling is, therefore, to allow entrants to offer a differentiated service and to develop their own commercial policy.

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 and has less interconnection points.

Price regulation of all these access services is inessential instrument for promoting competition and investment. Regulated access prices determine in which part of the incumbent's network the entrants will invest and influence both retail prices and service quality. In the EU, following the "ladder of investment" (LOI) regulatory model, NRAs set the prices of bitstream and direct access (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 Dögan, 2006; Waverman et al., 2007; Grajek and Röller, 2012; and Bacache et al., 2014). 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 literature on access regulation by assessing how the use of each type of entry at the country and at the operator level 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 on prices of several commercial strategies frequently used by operators, including bundling and market segmentation. Additionally, we assess the effects of the entry patterns (bitstream, LLU and own network) that are usually found in national markets.

We estimate a model for the prices of broadband residential plans (p_{moit}), where m is the offer, 'o' is the operator, '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. The price equation also includes the penetration of the service in each country and country and time fixed effects. Specifically, we estimate the following model:

Pricing Equation (1):

$$p_{moit} = \underbrace{a_0 + a_1 DownstreamSpeed_{mit} + a_2 UpstreamSpeed_{mit} + a_3 Technology_{mit}}_{\text{Technical characteristics}}$$
$$\underbrace{+ a_4 Bundling_{mit} + a_5 VoIP_{mit} + a_6 UnlimitedVolume_{mit} + a_7 VolumeCap_{mit} + a_8 NOffers_{oit}}_{\text{Commercial characteristics}}$$
$$\underbrace{+ a_9 Incumbent_{it} + a_{10} HHIPlat_{it} + a_{11} Bitstream_{it} + a_{12} Directaccess_{it} + a_{13} Ownnetwork_{it} + a_{14} BitstreamO_{oit} + a_{15} DirectaccessO_{oit}}_{\text{Measures of competition and regulation}}$$
$$+ a_{16} Penetration_{it} + a_{17} Country_i + a_{18} Time_t + e_{moit}$$

The prices of the plans offered by each operator may vary according to the quality of the service and the access technology. In Eq. (1), *DownstreamSpeed* is the downstream speed advertised in the plans' technical details. The speed of the service is one feature usually considered by consumers when they contract a plan because it determines how fast they can view web pages, receive e-mails, or download music, for example. *UpstreamSpeed* is the upstream speed offered in the plan and indicates the speed at which users can upload data to the Internet, which might include, for instance, uploading a file to a server, sending an email message or using peer-to-peer software. Operators usually assign much more downstream than upstream speed.[30] To account for a possible non-linear relationship between *Price* and *DownstreamSpeed* and *UpstreamSpeed* these variables are introduced in the model in logarithms. Technology is the access technology used to provide the service. This might be xDSL, cable modem or fibre (FTTx). We expect each technology to have a different effect on the price since they require different levels of investment and bandwidths, and because consumers might have different "perceptions" about their quality.

The price equation also includes the commercial practices that may be adopted

[30] Symmetric connections, such as Symmetric Digital Subscriber Line (SDSL), offer identical upstream and downstream rates but our data do not include any plan with this feature.

by operators. *Bundling* refers to the practice in which broadband access is provided together with voice telephony and/or television. Our basic estimations consider all the plans commercialized by operators and we include dummy variables to capture when the broadband service is bundled with other services. We have adopted this approach because we believe operators consider stand-alone and bundled broadband services to be partly substitutes when setting their prices. This is also the approach taken by the European Commission when it establishes its principles for analysing the broadband wholesale market.[31] Notice also that bundle subscriptions we assess the effects of the entry patterns (bitstream, LLU and own network) that are usually found in national markets are especially prevalent in the EU. According to DG CONNECT, in 2011 around 75% of all broadband subscriptions in the EU-15 were for bundled broadband plans.[32] In our data set, almost 60% of all plans are broadband packages. In spite of this, it could still be argued that stand-alone and bundled broadband are different services. For this reason, in Section 6 we present separate estimations for each type of plan.

The commercialization of broadband bundled together with other services might represent a cost saving for operators, owing, for example, to the existence of scope economies, but it might also imply additional costs that 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 fee. In other cases, bundling may be a marketing strategy used by operators to segment consumers or to increase their switching costs.[33]

The variable *VoIP* reflects the situation in which the broadband service is bundled together with voice telephony but provided over IP, which reduces the operators' costs (naked xDSL).

UnlimitedVolume is a dummy variable that shows if the plan offers unlimited broadband volume or if there is a restriction on the user's downloadable

[31] For instance, in its Explanatory Memorandum to the Recommendation on Relevant Product and Service Markets (SEC (2007) 1483/2), the European Commission considers that "In most case the individual services in the bundles are not good demand-side substitutes for each other yet may be considered to be part of the same retail market if there is no more independent demand for individual parts of the bundle".

[32] Specifically, broadband and voice, on the one hand, and broadband, voice and TV, on the other, accounted on average for 49% and 26% of all subscriptions to broadband plans in the EU 15. See http://ec.europa.eu/digital-agenda/en/scoreboard.

[33] Our data set does not allow us to identify if consumers can subscribe separately to each service ("menu à la carte") or if they are forced to contract the bundle (tying).

capacity. *VolumeCap* measures the volume of data that users can download if the plan has a capacity restriction. A priori, we expect capped offers to be cheaper than those with unlimited capacity, and also for the price of the plan to increase with the download limit. In spite of this, in a recent theoretical paper Economides and Hermalin (2013) have shown that operators might impose download limits in order to promote competition among content providers. This can increase consumer surplus and allow them to charge higher prices.

We also examine a group of variables that reflect the level of competition in the national markets. *Incumbent* is a dummy that identifies if incumbents have different pricing policies to those adopted by entrants. Incumbents may enjoy some market power thanks to reputational advantages or to the existence of consumer switching costs. They may also have cost advantages over their rivals. Yet, it is important to recall that European operators may be an incumbent in one country but an entrant in one or more other countries. Hence, operator costs need to be related to their presence in several countries and to their bargaining power with equipment providers. Notice also that incumbents might set higher retail prices in order to avoid the margin squeeze tests implemented by anti-trust authorities. As Carlton (2008) and Sidak (2008) argue, a price squeeze ban can act as an incentive to vertically integrated incumbents to increase their prices and so reduce the risk of antitrust lawsuits being brought by their competitors.[34]

HHIPlat is the Herfindahl–Hirschman Index (HHI) of concentration in terms of technology shares. A high *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 et al., 2010 and Gruber and Koutroumpis, 2013). In the price analysis, a factor that should be considered is that inter-platform competition allows operators to differentiate their services, which might offset price reductions generated with platform competition.

NOffers is the number of plans offered by each operator in each country and it is introduced in order to measure the effects of market segmentation on the

[34] Gaudin (2012) describes several recent price squeeze cases concerning regulated incumbent operators in Europe and the US.

prices. When competition is strong, operators can offer a large number of plans to better target specific groups of consumers, but when they have market power they can also segment the market to set higher prices. Hoernig (2001) also suggests that operators can release a large number of plans to generate some confusion among consumers and so as to be able to increase prices.

Finally, a principal objective of this study is to determine how the prevalence of different types of entry in a country (bitstream, direct access or the deployment of the entrant's own network) affects the operators' pricing strategies. *Bitstream, Directaccess*, and *Ownnetwork* are explanatory variables that reflect the relative importance of these entry patterns in each country with respect to the incumbent's number of lines.[35] The inclusion of these variables at the country level shows how different types of competition affect the operators' price decisions. In addition to this, the variables *BitstreamO* and *DirectaccessO* are the number of bitstream and direct access lines that each operator has in the country divided by its total number of lines. These variables should measure how the specific entry strategy adopted by an operator affects its prices. We believe that the use of bitstream and direct access by an operator will depend on the regulation of access charges, but also on other aspects such as the investment required to deploy the network, the operators' perceptions of consumers' willingness to pay for high quality services, or the regulatory institutions in the country.

In most European countries, broadband services are mainly provided by the legacy communication infrastructure, where the incumbent operator maintains significant market power. Taking this into account, we seek to examine the response of prices to different entry patterns. The variables *Bitstream, Directaccess*, and *Ownnetwork* are defined at the country level and should reflect the responses of operators to the type of competition in the country. By contrast, *BitstreamO* and *DirectaccessO* are defined at the operator level and should capture the influence of their cost structure.

---

[35] Notice the differences between *Ownnetwork* and *HHIPlat*. 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. 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.

Unfortunately, our data set does not contain any information about the number of subscribers to each plan. 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 or low density areas.

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
Price Broadband, Voice and TV (euros)	479	45.2	16.8	13.8	138.5
Price Metered Offers (euros)	410	36.7	14.7	7.1	79.8
Volume Cap (Gb)	410	64.0	135.9	0.4	1000
Download Speed (Mbps)	2204	23.8	32.6	0.1	500
Upstream Speed (Kbps)	2204	784.9	3444	0.1	60000
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

4. The data

We use a panel data set of residential retail broadband offers in 15 European Member States for the period 2008 to 2011. The 15 countries considered group more than 80% of the total broadband access lines offered in the EU-27 during this period. On average, the data set contains around 550 offers per year and an overall total of 2204 observations (Table 1). The sample includes the operators' plans that group more than 90% of the broadband subscribers in each country. Most of our data are drawn from Quantum-Web Ltd. Data for the countries' broadband penetration rates and socio-economic variables are provided by the European Commission Directorate General for Communications Networks, Content & Technology (DG-CONNECT), Eurostat, and the OECD.

The units of the dependent variable *Price* are euros adjusted by the country's purchasing power parity (PPP). Information about the prices and the technical characteristics of the plans is obtained primarily from the operators' web sites by Quantum-Web. The prices announced by operators might differ in some cases from those offered by operators via other sales channels (e.g.: operators' retail shops). Likewise, operators may offer discounts to retain their subscribers or to attract consumers away from their rivals.[36]

We have separate information about the monthly prices announced on the operators' websites and the landline rental. The sum of these two components is the monthly price of the Internet service considered in our estimations. Notice that xDSL operators usually present the monthly price and the landline rental separately in their offers, but cable modem and FTTx operators charge a single price.

Quantum-Web also offers information about non-recurring charges associated with the service (installation costs, routers, antennas, etc.). Customers usually pay these charges as a lump-sum payment at the beginning of the contract. Operators might use these costs strategically in order to attract consumers. Indeed, they may hide the information about the costs of some devices, such as routers, or some services, such as roaming. In practice, broadband consumers may not learn all the details of the price structure until after they have contracted the service.[37]

The inclusion of non-recurring costs in the price requires the use of some assumptions. On the one hand, we consider that all consumers incur these non-recurring costs, even those that are already subscribers to the operator. On the other hand, we assume an amortization period of 26 months for these costs, which is the average duration of the contracts in the EU according to the European Commission, 2011b.[38] Taking into account the effect that these assumptions might have on the interpretation of our results, we present separate estimations of the model with and without the non-recurring costs.

[36] The prices do not include the additional charges that consumers with metered plans have to pay when they exceed their capacity limits.
[37] The relevance of this problem is studied in Gabaix and Laibson (2006).
[38] We have also estimated the model considering an amortization period of non-recurring costs of 24, 36 and 48 months, obtaining similar results for our key variables. The results of these estimations can be obtained from the authors upon request.

The variables representing the downstream and upstream speeds are in logarithms. *DowsntreamSpeed* is measured in Mbps. The minimum speed in our sample is 0.128 Mbps and the maximum is 500 Mbps. However, a significant number of plans have a quality between 10 and 30 Mbps (Table 2). *UpstreamSpeed* is measured in Kbps. In our sample it ranges from 0.1 Kbps to 60,000 Kbps. The difference between downstream and upstream speeds is usually great, although it is smaller in FTTx and cable modem plans. On the other hand, note that in some cases the speeds promoted by operators might differ greatly from the actual speeds obtained by households. These differences can depend on various aspects such as the distance of the household from the operator's cabinet. Our data set only contains the information included on the operators' web sites and unfortunately we are unable to analyse whether these speeds and those actually offered by operators differ significantly.

The model also considers the technology used by the operators to provide the service. The variables *xDSL, Cable* and *FTTx* are dummy variables that take the value 1 when operators use these technologies to offer the service and 0 otherwise. It should be stressed that the downstream speed is related to the type of technology used to provide the service. Thus, xDSL cannot provide 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 FTTx can attain download speeds of 1 Gbps. The possibility of bundling the broadband access with other services also depends on the technology. While xDSL is usually bundled with voice telephony, cable modem and FTTx are able to support high quality TV services.

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

	Observa-tions	Number of Operators	Average Price (euros)	Average Download Speed (Mbps)	Average Upstream Speed (Mbps)	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	2.1	58%	20%	58.4	1.9%	12.9%	24.7%
Belgium	32	5	42.6	20.2	2.1	34%	56%	25.5	4.7%	3.7%	37%
Denmark	12	3	25.9	27.3	2.7	58%	42%	208.3	7.1%	9.6%	21.7%
Finland	26	4	26.4	27.5	1.5	0%	4%	0.1	2.8%	1.9%	63.1%
France	46	5	34.3	52.9	4.9	93%	-	-	7.6%	43.2%	7%
Germany	55	10	26.6	28.2	1.4	65%	2%	1.8	6.8%	35.7%	12.4%
Greece	33	5	40.3	18.6	0.9	61%	-	-	1.9%	55.7%	0%
Ireland	38	4	38.1	17.3	1.2	55%	63%	29.2	19.6%	5.1%	25.8%
Italy	26	6	29.1	10.6	0.6	42%	15%	0.1	14.0%	29.5%	3.8%
Luxembourg	19	3	36.3	18.6	0.6	32%	16%	1.4	0.0%	11.2%	19.0%
Netherlands	60	9	39.3	29.6	3.0	53%	-	-	1.8%	13.1%	39.5%
Portugal	33	5	53.1	69.4	5.2	88%	39%	18.2	2.2%	9.4%	40.1%
Spain	47	7	56.9	20.9	1.1	89%	2%	0.0	5.7%	24.1%	17.6%
Sweden	53	5	28.7	36.9	9.6	32%	-	-	4.0%	13.7%	38.8%
UK	39	6	30.7	23.4	1.5	67%	31%	7.0	10.7%	37.7%	21.4%

Source: Quantum Web-Ltd

Broadband access can be bundled with other services and commercialized at a single price. To identify the effect of this commercial strategy on the price we have created four dummy variables: *Stand-alone* broadband represents single broadband plans, Internet and voice indicates when broadband is offered together with voice telephony; Internet and tv when it is offered with television; and Internet, voice and tv when broadband is bundled with both voice and television.[39]

UnlimitedVolume is a dummy variable that takes a value of 1 for plans that offer unlimited downstream volume, and 0 for plans that have a volume cap. For metered plans, the variable *VolumeCap* measures the maximum number of GBs that can be consumed without paying an extra charge. Consumers pay an 'overage charge' when their consumption exceeds this limit, but as explained before we do not consider this charge in our analysis.[40]

Competition and regulation are essential factors in understanding the operators' pricing policy. Our data set contains information about the number

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

[40] Metered plans charge for the additional capacity consumed. The extra charges are usually paid per GB or per a discrete number of extra GB, but some plans establish charges per day, hour or minute above the cap limit. In some cases, operators do not charge an extra fee but the service experiences a sharp reduction in download speed once the cap has been exceeded (bandwidth throttling).

of lines per operator in each country, classified according to technology and type of access. Moreover, the European Commission provides data about the different types of access at an aggregated country level. We use this information to construct the variables that measure the entry patterns at the country and at the operator levels. *Bitstream* is the entrants' number of bitstream lines (Gig-ADSL or ADSL-IP) in the country divided by the incumbent's number of lines. Direct access is the entrants' number of direct access lines divided by the incumbent's number of lines. *Ownnetwork* is the entrants' number of own lines divided by the incumbent's number of lines. As such, these indexes show the relevance of alternative entry patterns in relation to incumbent size. On the other hand, *BitstreamO* is the operator's number of bitstream lines divided by its total number of lines, and *DirectaccessO* is the operator's number of direct access divided by its total number of lines.

We use other variables to measure the level of competition in each country. Incumbent is a dummy variable that takes a value of 1 when the operator is the incumbent in the country and 0 otherwise. *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). On the other hand, *NOffers* is the number of offers commercialised by each operator in each country and in each year.

Penetration is defined as the number of broadband subscriptions per 100 inhabitants in a country. For this variable 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.

Finally, the pricing equation includes country-fixed effects and year dummies, to account for the unobserved heterogeneity in each national market and to control for the evolution of prices during the period studied.

For illustrative purposes, Table 2 shows some characteristics of the broadband plans for each country in 2011. The table highlights across-country differences in terms of price and downloads speed. Direct observation of these statistics suggests that price differences may be explained by differences in the download speeds, but also by other factors such as bundling and volume caps.

The econometric analysis conducted in the next section seeks to identify the main factors determining the operators' prices.

5. Empirical strategy and results

This section presents an econometric multivariate analysis of the factors influencing broadband Internet access prices. We estimated the pricing equation using two procedures: ordinary least squares (OLS) and two-stage least squares (2SLS-IV).[41]

5.1. Methodology

The estimation of our model using OLS can result in a problem of endogeneity because a country's broadband prices can influence the number of subscribers. Indeed, we verified that the Hausman test for the exogeneity of the variable Penetration is rejected at the 1% significance level (Table 3). In such a case, the OLS coefficients of *Penetration* could be biased downwards, and so we might erroneously conclude that penetration has a smaller effect on price than it actually does. In order to solve this problem we used instrumental variable techniques and we examined different socio-economic variables as potential instruments for *Penetration*. The instruments should be variables that are correlated with the penetration of the broadband service but uncorrelated with the error term in Eq.(1). We considered using the following variables as instruments: *GDPpc* – the gross domestic product per capita; *Unemployment* – the percentage of people unemployed in the country; *Density* – the number of inhabitants in the country divided by its area in square kilometers; *Digitalskills* – the proportion of the population having at least low digital skills;[42] and *PC* – the percentage of personal computers per household. We also considered using the lags of the variable *Penetration* as instruments. Data for *GDP, Unemployment* and *Density* were obtained from Eurostat, *Digitalskills* from the Digital Agenda Scoreboard (DG-CONNECT) and PC penetration from the OECD

[41] Our model includes country fixed effects. We have ruled out the use of a random effects model because the unobserved heterogeneity (the unobserved firm or country characteristics) is correlated with the explanatory variables in the pricing equation.

[42] The European Commission defines digital skills as "the confident analytical use of information society technology (IST) for work, leisure, learning and communication".

broadband statistics.

We expect *GDPpc, Density, Digitalskills* and *PC* to have a positive effect on the adoption of Internet and *Unemployment* to have a negative effect. *GDPpc* should be a good instrument because it affects Internet penetration but it should not influence the operators' pricing strategy. In addition, both *Price* and *GDPpc* were adjusted by the country's PPP so as to account for differences in the cost of living across EU countries. *Density* should be related to the historical deployment of telecommunications networks and should affect the coverage of Internet. However, we do not expect the prices set by operators to be affected by the density at the national level. As for *Digitalskills*, we expect the percentage of the population with some knowledge in the use of ICTs to be related to Internet penetration, but digital skills in the country should not be related to the operators' pricing policies. Similarly, *PC* should have a positive effect on the adoption of Internet but we do not expect an impact of PC on broadband prices since computers have other uses aside from accessing the Internet and because there are other devices such as laptops, notebooks, tablets and mobile phones that can be used to access the Internet.

Table 3 presents the econometric tests that examine the suitability of our panel of candidates for instruments. All the specifications considered passed Hansen's J test for over-identifying restrictions. Moreover, we applied the instrument suitability tests (the F-statistic in the first stage regression of the variable *Penetration*) to verify that the instruments are strong. In spite of this, notice that Hansen's J test has a lower p-value when we consider the *GDPpc*. Taking this into account, we eventually chose as instruments *Unemployment, Density, Digitalskills* and PC in order to maintain the efficiency of the model.

Likewise, it should be noted that the competition and regulatory variables might also be affected by an endogeneity problem since the entrants' entry patterns could be determined simultaneously with prices. Yet, a high value for *Bitstream, Directaccess* and *Ownnetwork* might also reflect the greater efficiency of entrants, or the fact that consumers consider that entrants offer a better service. To account for this situation, the model includes country fixed effects to capture the unobserved characteristics that influence the efficiency of operators and, eventually, the retail prices. Examples of these unobserved effects include investments, administrative constraints, and state aid plans that are specific to each country.

5.2. Estimation results

Table 4 reports the OLS and 2SLS estimates of the pricing equation. We present three specifications for the OLS regression: Specification 1 considers the technical characteristics of the offers and the commercial strategies of the operators; Specification 2 also includes the competition and regulatory variables at the country level and *Penetration*,[43] and Specification 3 adds the access variables at the operator level. We also show three specifications of the model estimated with 2SLS. Specification 4 considers all the variables except the access variables at the operator level, Specification 5 considers all variables, and Specification 6 considers all variables when prices include the non-recurring costs. All specifications include country fixed effects and year dummy variables.

The estimates of the pricing equation are robust to the alternative specifications considered. Moreover, most of the coefficients in the regressions are significant and their signs are in line with our predictions. In the case of *Penetration* we find that the coefficient is negative and significant, except in Specification 4 when we do not include the access variables at the operator level.[44] Observe also that the *Penetration* coefficient is larger, in absolute terms, when we apply 2SLS-IV (Specifications 4 to 6) than in the OLS regression (Specifications 1 to 3), which suggests that the OLS *Penetration* coefficient is biased downwards ($\tilde{\beta}_{\text{Penetration-OLS}}$= -0.008 compared to $\tilde{\beta}_{\text{Penetration-2SLS}}$=-0.011). The 2SLS Penetration coefficient shows that a one percentage point increase in the penetration level is followed by a 1.1% fall in price.[45]

[43] Since the dependent variable Price is included in logs, Penetration is interpreted as a semi-elasticity.

[44] The computed standard errors are robust to any bias from heteroskedasticity and they are also clustered according to observations from the same country. We tested for multicollinearity using the *variance inflator factor* (*VIF*) obtaining values below 3.

[45] We also estimated the model using the lagged *Penetration* variable as our instrument. We found that this instrument mitigates the endogeneity problem although not completely. Nevertheless, it confirms that the simultaneity bias of the *Penetration* coefficient is downwards.

Table 3: Endogeneity test for *Penetration*

Hausman endogeneity test. Ho: *Penetration* exogenous	p-value= 0.0000			
Instruments for *Penetration*	*GDPpc, Unemployment, Density, Digitalskills, PC*	*GDPpc, Density, Digitalskills, PC*	*Unemployment, Density, Digitalskills, PC*	*Density, Digitalskills, PC*
Test	**Test Result 1**	**Test Result 2**	**Test Result 3**	**Test Result 4**
Hansen J test. Ho: instruments exogenou	p-value=0.1079	p-value=0.0578	p-value=0.9263	p-value=0.4993
Validity of Instruments Ho: weak instrun	p-value=0.0000	p-value=0.0000	p-value= 0.0000	p-value=0.0001

Table 4: Estimation Results (OLS and 2SLS): All Broadband Plans

Dependent variable	**Specification 1**	**Specification 2**	**Specification 3**	**Specification 4**	**Specification 5**	**Specification 6**
Log Price (*Price*)	**OLS**	**OLS**	**OLS**	**2SLS-IV**	**2SLS-IV**	**2SLS-IV**
Independent variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Penetration	**-**	**-0.006****	**-0.008*****	**-0.008**	**-0.011****	**-0.011****
		(0.010)	(0.001)	(0.138)	(0.03)	(0.023)
Log Speed (DownstreamSpeed)	**0.145*****	**0.135*****	**0.134*****	**0.132*****	**0.127*****	**0.122*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log Upstream (UpstreamSpeed)	**0.006**	**0.001**	**-0.004**	**-0.001**	**-0.008**	**-0.006**
	(0.759)	(0.973)	(0.857)	(0.962)	(0.724)	(0.776)
Technology dummy (reference: xDSL)						
Cable	**-0.091**	**-0.111****	**-0.098**	**-0.118*****	**-0.108**	**-0.087**
	(0.117)	(0.046)	(0.266)	(0.01)	(0.166)	(0.27)
FTTx	**-0.045**	**-0.066**	**-0.074**	**-0.072****	**-0.085****	**-0.073***
	(0.263)	(0.128)	(0.128)	(0.044)	(0.032)	(0.071)
UnlimitedVolume	**0.133***	**0.143****	**0.148****	**0.144****	**0.150****	**0.140****
	(0.073)	(0.045)	(0.036)	(0.019)	(0.013)	(0.017)
VolumeCap	**0.0005****	**0.0005****	**0.0005***	**0.0005****	**0.0005****	**0.0004****
	(0.047)	(0.034)	(0.053)	(0.016)	(0.028)	(0.047)
Bundling (reference: stand-alone broadband)						
Internet and voice	**0.115*****	**0.111*****	**0.116*****	**0.112*****	**0.118*****	**0.118*****
	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Internet and tv	**0.164*****	**0.164*****	**0.164*****	**0.166*****	**0.169*****	**0.173*****
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Internet, voice and tv	**0.323*****	**0.304*****	**0.310*****	**0.304*****	**0.310*****	**0.313*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VoIP	**-0.014**	**-0.038**	**-0.060***	**-0.038**	**-0.060***	**-0.068****
	(0.727)	(0.245)	(0.086)	(-0.200)	(0.046)	(0.032)
Incumbent	**0.145*****	**0.120*****	**0.138***	**0.118*****	**0.136****	**0.154****
	(0.001)	(0.004)	(0.071)	(0.000)	(0.042)	(0.023)
HHIPlat	**-**	**0.007**	**0.004**	**0.007**	**0.004**	**0.004**
		(0.195)	(0.373)	(0.158)	(0.343)	(0.339)
Bitstream	**-**	**0.482****	**0.535****	**0.479*****	**0.526*****	**0.420****
		(0.011)	(0.013)	(0.003)	(0.003)	(0.013)
Directaccess	**-**	**-0.212****	**-0.301*****	**-0.204*****	**-0.288*****	**-0.260*****
		(0.011)	(0.006)	(0.004)	(0.001)	(0.002)
Ownnetwork	**-**	**0.093**	**-0.089**	**0.089**	**-0.107**	**-0.055**
		(0.736)	(0.768)	(0.735)	(0.708)	(0.836)
BitstreamO	**-**	**-**	**0.067**	**-**	**0.066**	**0.075**
			(0.254)		(0.224)	(0.188)
DirectaccessO	**-**	**-**	**-0.014**	**-**	**-0.010**	**0.014**
			(0.874)		(0.900)	(0.861)
NOffers	**-**	**0.012****	**0.014****	**0.012*****	**0.015*****	**0.015*****
		(0.033)	(0.015)	(0.009)	(0.001)	(0.001)
Constant	**3.283*****	**2.855*****	**3.142*****	**2.882*****	**3.200*****	**3.195*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R^2	*0.556*	*0.570*	*0.593*	*0.569*	*0.591*	*0.591*
Number of observations (N)	*2204*	*2204*	*2003*	*2204*	*2003*	*2003*

Note: All specifications include country and year dummies which are not reported for brevity. Year dummies are not statistically significant. Standard errors are robust to heteroskedasticity and are clustered by country. P-values are in parenthesis. Significance at * 10%, ** 5%, *** 1% level.

As expected, *DownstreamSpeed* increases broadband prices. Specifically, a 10% increase in speed raises broadband prices by around 1.3%. On the other hand, the coefficient of *UpstreamSpeed* is not significant.

As for technologies, xDSL appears to be more expensive than cable modem and FTTx, although the coefficient of cable is not significant in Specifications 5 and 6. Fibre and cable modem technologies can provide higher speeds and better quality than xDSL, but this might not be sufficient to enable operators to charge higher prices per Mbps. Such a situation might reduce the operators' incentives to invest in New Generation Access Networks (NGAs) and constitutes an obstacle to the authorities' objective of promoting the extension of broadband networks. One explanation for this finding is that xDSL is often the only available technology in many locations. Operators using xDSL can set a higher price per Mbps because they only face competition from cable modem and fibre in specific locations, whereas cable modem and fibre operators are usually present in densely populated areas where there are several competitors. A complementary explanation is that cable and fibre operators commercialize plans with a higher downstream speed and cannot establish a proportional increase in prices.

As for the operators' commercial strategies, plans with unlimited download capacity have prices that are around 15% higher than those with download restrictions. In the case of metered plans, the coefficient of the variable *VolumeCap* is positive and significant but very small. Indeed, one additional GB increases the price of the metered plan by 0.05%. We also find that bundles of broadband and other services are more expensive than stand-alone broadband plans. Plans combining broadband with voice and broadband with TV are 13% and 18% more expensive than standalone plans, respectively.[46] On the other hand, plans that combine broadband, voice telephony and television are 36% more expensive. By contrast, plans that include broadband and voice over IP are about 6% cheaper.

Competition variables also offer interesting results. Incumbents' plans are around 15% more expensive than entrants' plans, which might be explained by the formers' dominant position in the market and/or by the existence of an "umbrella effect". As explained above, when the regulatory authorities ban price squeezes, vertically integrated incumbents might raise their retail prices and generate "price umbrellas" for their competitors. *Noffers* exhibit a positive effect on prices, suggesting that firms can set higher prices when they are

[46] The coefficients of dummy variables in semi-logarithms models are interpreted as the percentage difference of 100 exponential [(coefficient)-1] with respect to the reference (Halvorsen and Palmquist, 1980).

better able to screen consumers. We also find that technological concentration, measured with the variable *HHIPlat*, has a positive sign but it is not significant in any specification.

Specifications 2-6 show that country entry patterns are a factor that explains broadband prices. In particular, we find that the intensity in the use of *Bitstream* at the country level has a positive effect on broadband prices and that the use of *Directaccess* (LLU) reduces prices. On the other hand, the estimations reveal that *Ownetwork* does not have a significant statistical effect. It is also interesting to highlight that the coefficient associated with *Bitstream* almost doubles that associated with *Directaccess*. Indeed, with an increase of 0.1 units in the *Bitstream* index there is an increase of 5% in the price of the plan, whereas with the same increase in the *Directaccess* index there is a reduction of 3% in the price. This implies that with an equivalent change in these variables 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 imply smaller price reductions for equivalent levels of entry. Finally, the coefficients of *BitstreamO* and *DirectaccessO* have the expected sign, but they are very small and are not significant. All in all, these results imply that the operators' pricing policies are influenced by the entry patterns present in the country, but that they do not respond to their own network configuration.

6. Discussion

Our analysis in the previous section shows that two key factors – operators' bundling strategies and their entry patterns in a country – are essential for understanding the way in which operators set their prices. Below we discuss them in more detail.

6.1. Bundling strategies

A commercial policy widely adopted by telecom operators is that of bundling several services together in the same offer. Our estimations in the previous section considered all the plans offered to consumers and we included several dummy variables in the pricing equation to identify the effects of bundling

(Table 4). In spite of this, it could be considered that operators use different commercial strategies when setting the prices of standalone and bundled plans. For example, they could set the prices taking into account that each type of plan is addressed to consumers with different quality preferences or different willingness to pay. They could also use different technologies in each type of service. In order to analyse this situation, we have re-estimated the model in Eq. (1) separating standalone and bundled plans. Below we explain that the main results obtained in Table 4 are robust to this alternative estimation strategy.[47]

Table 5 shows the estimates of the pricing equation when we separate standalone broadband and bundles of broadband and voice telephony. In the 2SLS-IV estimations, Penetration is instrumented by the same group of socio-demographic variables as before, but now we obtain that the coefficient is only significant for the case of stand-alone broadband.[48] By contrast, the coefficient of *HHIPlat* is now significant for standalone plans, indicating that a higher concentration of one technological platform (i.e., less inter-platform competition) raises prices per Mbps.

As for the variables that reflect the operators' entry patterns, we obtain similar results to those in Table 4. The coefficients associated with *Bitstream* and *Directaccess* maintain the same sign for both OLS and 2SLS-IV estimations, although *Directaccess* is now not significant for bundled offers. Notice also that the variable *DirectaccessO* is negative and significant for broadband plans, which implies that operators that make an intensive use of this type of entry set lower prices.

At this point, it is interesting to discuss the factors that might serve as incentives to operators to commercialize bundles. The economic literature reports that bundling enables operators to price discriminate between customers and it allows them to extract a larger part of the consumer surplus.[49] Bundling can also generate cost savings due to the presence of economies of scale and scope in the production of the services. Finally,

---

[47] Wallsten and Riso (2010) adopt a similar approach when analysing bundling.

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

[49] See for example Adams and Yellen (1976), Evans and Salinger (2005), McAfee, McMillan and Whinston (1989), Nalebuff (2004), and Prince and Greenstein (2014).

bundling acts as a "lock-in" strategy that increase the operators' market power. From the consumers' perspective, bundles can also be attractive because they might mean lower prices and they might reduce nuisance (i.e., consumers receive a single bill and have a unique customer helpline).

In our data set, stand-alone offers represent 41% of all the plans, bundles that combine broadband and voice account for 32% of the plans, and bundles of broadband and TV represent only 5% of all the plans, and are mainly sold by cable operators or xDSL incumbents. Triple packages (broadband, voice and TV) represent 22% of the plans and are the preferred combination of cable operators. It would be very useful to know the number of subscribers to each type of plan, but as pointed out above, this information is not available.

The lack of information about the consumption patterns of Internet users in each country and about the operators' costs prevents us from studying the bundling decisions of operators in more detail. In spite of this, Table 6 illustrates the differences in the bundling strategies of incumbents and entrants in the 15 countries studied. Direct inspection of the table shows that incumbents use xDSL in 92% of their plans, and that 39% of these are standalone plans. By contrast, entrants use xDSL in 50% of their plans, cable modem in 37% and fibre in the remaining 13%. Interestingly, regardless of the technology, around 40% of the entrants' plans are standalone plans. This implies that on aggregate terms incumbents and entrants differ in the type of technology offered, but both of them use a similar mix of bundled and unbundled plans.

Finally, we ran different regressions that consider the effect of competition and the entry patterns on the percentage of bundled plans offered by firms.[50] While we can certainly not interpret the coefficients of these simple cross-sectional regressions as causal, we have found that bundling is positively related with the intensity in the use of direct access at the operator and country level, and this result is robust to different model specifications. This result is in line with the intuition that LLU enables entrants to use innovative and diversified commercial practices.

[50] These estimations are restricted to xDSL plans and are available from the authors. First, we analysed a linear model that examines the proportion of bundled broadband plans offered by each operator and, then, we estimated a logistic model to analyse the factors influencing the operators´ decisions to offer bundles.

6.2. Entry pattern

One of the main results that emerges from our analysis is that broadband prices are higher in countries where entrants make greater use of bitstream entry and lower in countries where they make a more intensive use of direct access. Moreover, each entry pattern has a different effect on broadband prices. Thus, for example, in Specification 5 of Table 4, we found that $\tilde{\beta}_{Bitstream}$=0.526 and $\tilde{\beta}_{Directaccess}$=-0.288, which illustrates the greater sensitivity of prices to bitstream access. This result can be accounted for by the fact that direct access requires entrants to make major investments and because it allows operators to differentiate their products (Nardotto, Valletti and Verboven, 2012). Thus, for an equivalent increase in the use of these access mechanisms, the prices show a greater reaction to the increase in *Bitstream*.

In recent years, access-charge regulations in the EU Member States have been designed to acts an incentive to the progressive increase in the investments made by entrants, but very little is known about how this regulatory strategy affects retail prices. Most NRAs have followed the LOI approach, which involves setting higher access prices for bitstream so as to induce entrants to use direct access (Cave, 2006; Höffler, 2007; Bourreau et al., 2010). This measure has been effective in forcing the migration from bitstream access lines to LLU, but it has not been sufficient to encourage entrants to deploy their own networks (Bacache et al., 2014). Our paper shows that the application of the LOI has also had important implications for broadband prices. The LOI implies higher costs for the operators using bitstream, but even operators that have a small dependence of the incumbents' networks can set high prices if they observe that in the country there is a high prevalence of bitstream access and consider that this weakens competition. This finding should be taken into account by the authorities when they regulate the wholesale broadband market.

Our results also suggest that, during the period analysed, intra-platform facility-based-competition was more effective in reducing prices than was intra-platform service-based-competition. On the other hand, only when we analysed stand-alone broadband plans separately did we observe that inter-platform competition generated lower prices (see the coefficient of *HHIPlat* in Table 5).

Cable modem and FTTx plans involve lower prices per Mbps than those charged by xDSL plans, but these technologies also offer more downstream speed and additional services such as TV, which increase the final price paid by consumers. A further aspect that should be considered when interpreting our results is that although we introduced the *HHIPlat* index at the national level to measure the relevance of the inter-platform competition, cable modem and fibre are usually only present in certain regions or locations of a country. As a consequence, even if the *HHIPlat* index is low in the country there might be little competition between technologies.

Table 5: Estimation Results (OLS and 2SLS): Stand-alone Broadband and Bundles

Dependent variable	**Stand-alone Broadband**		**Broadband + Fixed Voice**	
Log Price (Price)	**OLS**	**2SLS-IV**	**OLS**	**2SLS-IV**
Independent variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Penetration	**-0.007*****	**-0.024***	**-0.006*****	**-0.001**
	(0.001)	(0.081)	(0.006)	(0.894)
Log Speed (DownloadSpeed)	**0.131*****	**0.116*****	**0.132*****	**0.142*****
	(0.000)	(0.000)	(0.000)	(0.000)
Log Upstream (UpstreamSpeed)	**0.027**	**0.005**	**-0.038**	**-0.033**
	(0.383)	(0.843)	(0.267)	(0.259)
Technology dummy (reference: xDSL)				
Cable	**-0.071**	**-0.123**	**-0.157****	**-0.146****
	(0.617)	(0.341)	(0.022)	(0.015)
FTTx	**-0.122***	**-0.185****	**-0.049**	**-0.039**
	(0.068)	(0.028)	(0.45)	(0.499)
UnlimitedVolume	**0.110**	**0.115***	**0.219***	**0.221****
	(0.113)	(0.096)	(0.062)	(0.031)
VolumeCap	**0.0002**	**0.0002**	**0.0006****	**0.0007*****
	(0.512)	(0.585)	(0.015)	(0.003)
VoIP	**-**	**-**	**-0.091***	**-0.090****
			(0.071)	(0.044)
Incumbent	**0.185**	**0.164**	**0.088**	**0.087**
	(0.150)	(0.133)	(0.218)	(0.174)
HHIPlat	**0.010***	**0.010****	**0.005**	**0.005**
	(0.094)	(0.018)	(0.429)	(0.454)
Bitstream	**0.727****	**0.697****	**0.404****	**0.396*****
	(0.036)	(0.014)	(0.017)	(0.008)
Directaccess	**-0.618*****	**-0.537*****	**-0.111**	**-0.117**
	(0.008)	(0.004)	(0.423)	(0.396)
Ownnetwork	**-0.749**	**-0.753**	**0.303**	**0.354**
	(0.185)	(0.131)	(0.479)	(0.389)
BitstreamO	**0.199**	**0.190**	**-0.071**	**-0.077**
	(0.156)	(0.141)	(0.403)	(0.321)
DirectaccessO	**0.078**	**0.078**	**-0.122***	**-0.129****
	(0.565)	(0.545)	(0.051)	(0.017)
NOffers	**0.004**	**0.004**	**0.002**	**0.002**
	(0.000)	(0.000)	(0.696)	(0.651)
Constant	**2.854*****	**3.087*****	**3.224*****	**3.175*****
	(0.5527)	(0.5099)	(0.5361)	(0.484)
R^2	*0.512*	*0.440*	*0.608*	*0.603*
Number of observations (N)	*796*	*796*	*631*	*631*

Note: All specifications include country and year dummies which are not reported for brevity. Year dummies are not statistically significant. Standard errors are robust to heteroskedasticity and are clustered by country. P-values are in parenthesis. Significance at * 10%, ** 5%, *** 1% level.

Table 6: Number of Plans (Percentanges) by type of Bundle across Technologies and Incumbent and Entrants (I/E)

Bundling (Incumbent/Entrant)	xDSL	Cable Modem	FTTx	Total plans (I/E)
Single Broadband (I/E) *	204 (39%) / 352 (43%)	0/ 257 (42%)	16 (40%) /80 (37%)	220 (39%) / 689 (42%)
Broadband & Voice (I/E) *	148 (28%) / 350 (43%)	0 / 125 (20%)	12 (30%) / 64 (30%)	160 (28%) / 539 (33%)
Broadband and TV (I/E) *	41 (8%) / 6 (1%)	4 (100%) / 46 (8%)	4 (10%) / 19 (9%)	49 (9%) / 67 (4%)
Broadband, Voice and TV (I/E) *	130 (25%) / 105 (13%)	0 / 184 (30%)	8 (20%)/ 53 (25%)	138 (24%) / 342 (21%)
Total Plans (I/E) ^	523 (92%) / 813 (50%)	4 (1%)/ 608 (37%)	40 (7%) / 216 (13%)	567 (100%) / 1637 (100%)

* The percentages in brackets for bundles are measured with respect to the number of plans for each technology.
^ The percentages in brackets of all plans by technology are calculated with respect to the total number of plans.

7. 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 focused on three types of variables: (1) the technical characteristics of the plans; (2) the operators' commercial strategies; and (3) the regulation and competition in the country. Besides, we controlled for the potential endogeneity of broadband penetration by using the instrumental variable approach (2SLS-IV) and employed as instruments a group of socio- economic variables.

Our analysis reveals that downstream speed is a significant driver of the price in broadband plans: a 10% increase in the download speed causes prices to rise by around 1.3%. Additionally, the price per Mbps of cable modem and fibre technologies is lower than that of xDSL, although the plans that use these technologies usually offer higher download speeds and bundle broadband access with voice telephony and/or television. In this context, an important policy question that emerges is whether consumer willingness to pay for cable modem and fibre plans is sufficiently high to encourage operators to invest in NGAs.

The operators' marketing strategies also play an important role in determining the prices. When the broadband service is bundled with voice telephony, the price increases by more than 10% and when it is bundled with both voice telephony and television it increases by around 36%. By contrast, when consumers contract the voice service through VoIP they obtain some price reductions. An interesting question for future research would be to examine the factors that act as an incentive to operators to offer bundled services and to analyse the effects of these practices on the level of competition.

The paper has also contributed to the literature that analyses the effects of access regulation in the broadband market. We show that broadband prices are higher in countries where entrants make greater use of bitstream access and lower in countries making greater use of LLU. We find little evidence that inter-platform competition and stand-alone entry (the last rung on the "ladder of investment" approach) reduce prices. Operators that rely mainly on their own networks might be offering high quality products that are more expensive or that experience less competition. All in all, our results confirm the benefits of facilitating the migration from bitstream to LLU entry, but they are less conclusive regarding the relevance of inter-platform competition for prices.

One limitation of our study is that we have not considered mobile broadband plans offered via smartphones or dongles. Mobile broadband demand is booming and future research should consider its impact on the prices of fixed and mobile broadband plans. For example, a rising number of operators are currently offering packages of mobile and fixed broadband services and this might modify the pricing strategies of operators and competition.

References

Adams, W. and Yellen, J., 1976. "Commodity bundling and the burden of monopoly", *Quarterly Journal of Economics*, 90, 475-98.

Andrés, L., Cuberes, D., Diouf, M., and Serebrisky, T., 2010. "The diffusion of the Internet: A cross-country analysis", *Telecommunications Policy,* 34, 323-340.

Armstrong, M., 2002. "The theory of access pricing and interconnection", *Handbook of Telecommunications Economics*, Vol. I, Elsevier: Amsterdam, 297-384.

Bacache, M., Bourreaum M., and Gaudin, G., 2014. "Dynamic Entry and Investment in New Infrastructures: Empirical Evidence from the Fixed Broadband Industry", *Review of Industrial Organisations, forthcoming*, 44 (1), 179-209.

Bouckaert, J., Van Dijk, T., and Verboven, F., 2010. "Access regulation, competition, and broadband penetration: An international study", *Telecommunications Policy*, 34, 661-671.

Bourreau, M. and Dögan, P., 2006. "Build or Buy Strategies in the Local Loop", *American Economic Review, Papers and Proceedings*, 96 (2), 72-76.

Bourreau, M., Dögan, P., and Manant, M., 2010. "A critical review of the ladder of investment approach", *Telecommunications Policy*, 34 (11), 683-696.

Briglauer, W., Ecker. G., and Gugler, K., 2013. "The impact of infrastructure and service-based competition on the development of next generation access networks: recent evidence from the European member states", *Information Economics and Policy*, 25, 142-153.

Calzada, J. and Martínez-Santos, F., 2014. "Broadband prices in the European Union: Competition and commercial strategies", *Information Economics and Policy*, 7, 24–38.

Cambini, C. and Jiang, Y., 2009. "Broadband Investment and Regulation: A literature Review," *Telecommunications Policy*, 33 (10-11), 559-574.

Carlton, D., 2008. "Should Price Squeeze be a Recognized Form of Anticompetitive Conduct?", *Journal of Competition Law and Economics*, 4 (2), 271-278.

Cava, I. and Alabau A., 2006. "Broadband policy assessment: a cross national empirical analysis", *Telecommunications Policy*, 30, 445-463.

Cave, M., 2006. "Encouraging infrastructure competition via the ladder of investment", *Telecommunications Policy,* 30, 223–237.

Czernich, N., Falck, O., Kretschmer, T. and Woessmann, L., 2011. "Broadband Infrastructure and Economic Growth", *The Economic Journal*, 121 (May), 505-532.

Distaso, W., Lupi, P. and Manenti, G., 2006. "Platform Competition and Broadband Uptake: Theory and Empirical Evidence", *Information Economics and*

Policy, 18 (1), 87-106.

Economides, N. and Hermalin, B.E., 2015. "The Strategic Use of Download Limits by a Monopoly Platform", forthcoming in *Rand Journal of Economics*, 46, 2, 297-327.

European Commission, 2009. "15th Progress Report on the Single European Electronic Communications Market – 2009".

European Commission, 2011. "Broadband Internet Access Costs (BIAC)". Final Report, Information Society and Media Directorate-General.Van Dijk – Management Consulting.

Evans, D. and Salinger, M., 2005. "Why do firms bundle and tie? Evidence from competitive markets and implications for tying law", *Yale Journal on Regulation*, 22, 37-89.

Gabaix, X. and Laibson, D., 2006. "Shrouded attributes, consumers myopia, and information suppression in competitive markets", *Quarterly Journal of Economics*, 121 (2), 505-540.

Galperin, H., 2012. "Prices and quality of broadband in Latin America: Benchmarking and trends", *Economics of Networks eJournal* 4(64).

Gaudin, G., 2012. "Price Squeeze and Monopoly Maintenance in Regulated Industries, mimeo.

Grajek, M., and Röller, L-H., 2012. "Regulation and investment in network industries: Evidence from European telecoms", *Journal of Law and Economics*, 55 (1): 189-216.

Greenstein, S. and McDevitt, R., 2011. "Evidence of a modest price decline in US broadband services", *Information, Economics and Policy*, 23 (2), 200-211.

Gruber, H., and Koutroumpis, P., 2013. "Competition enhancing regulation and diffusion of innovation: the case of broadband networks", *Journal of Regulatory Economics*, 43: 168-195.

Halvorsen, R. and Palmquist, R., 1980. "The Interpretation of Dummy Variables in Semilogarithmic Equations", *The American Economic Review*, Vol. 70, No. 3, 474-475.

Hazlett, T. and Bazelon, C., 2005. "Regulated Unbundling of Telecommunications Networks: A Spetting Stone to Facilities-Based Competition", mimeo.

Hoernig, S., 2001. "Collusion and confusion?", mimeo.

Höffler, F., 2007. "Cost and benefits from infrastructure competition. Estimating welfare effects from broadband access competition", *Telecommunications Policy, 31*(6-7), 401-418.

Laffont, J. and Tirole, J., 2000. "*Competition in Telecommunications"*, Cambridge, Mass, *The MIT Press*.

Lee, S., Marcu, M. and Lee, S., 2011. "An Empirical analysis of fixed and mobile broadband diffusion", *Information Economics and Policy*, 23, 227-233.

McAfee, R.P., McMillan, J. and Whinston, M.D., 1989. "Multiproduct Monopoly, Commodity Bundling, and Correlation of Values", *The Quarterly Journal of Economics*, MIT Press, Vol. 104(2), 71-83, May.

Nalebuff, B., 2004. "Bundling as an entry barrier", *Quarterly Journal of Economics*, 119, 159-87.

Nardotto, M., Valletti, T. and Verboven, F., 2014. "Unbundling the Incumbent: Evidence from UK broadband," CEIS Research Paper 331, Tor Vergata University, CEIS.

Pereira, P. and Ribeiro, T., 2010. "The impact on broadband access to the Internet of the dual ownership of telephone and cable networks", *International Journal of Industrial Organisations,* 29, 283–293.

Prat, A. and Valleti, T., 2003. "Spectrum Auctions Versus Beauty Contests: Costs and Benefits", en Mario Baldassarri y Luca Lambertini (eds.), Antitrust, *Regulation and Competition*, Palgrave Macmillan, London.

Prince, J. and Greenstein, S., 2014. "Does service Bundling reduce churn", *Journal of Economics and Management Strategy*, forthcoming.

Sidak, J.G., 2008. "Abolishing the Price Squeeze as a Theory of Antitrust Liability", *Journal of Competitive Law and Economics*, 4 (2), 279-309.

Teppayayon, O. and Bohin, E., 2010. "Functional separation in Swedish broadband market: Next step of improving competition", *Telecommunications Policy,* 34, 375-383.

Vogelsang, I., 2003. "Price Regulation of access to telecommunications networks", *Journal of Economic Literature*, 41 (3).

Wallsten, S. and Riso J.L., 2010a. "Residential and Business Broadband Prices: Part 1: An Empirical Analysis of Metering and Other Price Determinants", Technology Policy Institute.

Wallsten, S. and Riso, J.L., 2010b. "Residential and Business Broadband Prices: Part 2: International comparisons", Technology Policy Institute.

Waverman, L., Leschi, M., Reillier, B., and Dasgupta, K., 2007. "Access regulation and Infrastructure Investment in the Telecommunications Sector: An empirical Investigation", mimeo.

Chapter 3

Pricing strategies and competition in the mobile broadband market

1. Introduction

This paper analyses how mobile operators set the prices of mobile broadband plans. Mobile services have experienced an extraordinary growth worldwide. In 2012, the number of mobile phone users reached 4.4 billion and the penetration rate of mobile lines was 89% (6.6 billion SIM cards). The development of mobile contents and mobile applications has produced important changes in the communications habits of the population. In addition to making phone calls, consumers use smartphones to make video-conferences, navigate web pages, share files such as pictures and high definition videos, and play online games. As a result, nowadays an important part of the revenues generated by operators are originated by data traffic rather than by phone calls and SMS messages. This increase of data traffic has made necessary to deploy 3G and 4G networks in order to offer more download capacity to users.[51]

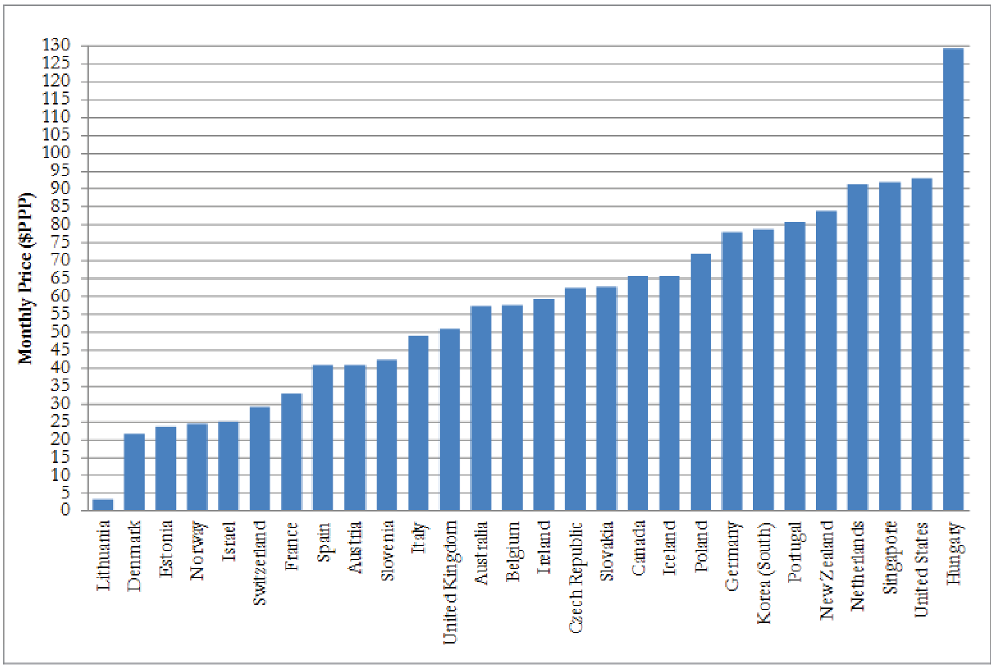
The transformation of the mobile market has led operators to introduce complex tiered pricing schemes with the objective of improving traffic management and of extracting the maximum surplus from consumers. Under tiered pricing, operators offer a menu of plans with a certain data allowance per month at a fixed rate. The plans include overage charges for the case in which consumers exceed data caps. They also offer minute allowances to make phone calls and might specify the speed of the service. Some operators also offer unlimited usage plans for heavy users of broadband services.

The use of this pricing structure has generated an important debate in the sector that has found an audience in antitrust authorities (Lyons, 2013). While some consumers associations and large content providers have alerted that monthly consumption limits creates artificial scarcity and allow operators to

[51] Indeed, although the first smartphones appeared in the nineties, its widespread adoption has been possible with the introduction of new generation wireless networks.

reduce future network upgrades, supporters of usage broadband pricing claim that this policy align costs to the intensity of use and shifts more network costs onto heavier users. Indeed, with a flat rate all users contribute equally to cover the network's costs, although heavier consumers use more of the network capacity. By contrast, usage-based tariffs can reduce the cost of lighter users and promote Internet adoption. Moreover, it alleviates network congestion and promotes an efficient use of broadband capacity. The objective of this paper is to contribute to this debate by empirically analyse what drives operators pricing strategies and to understand price differences across countries (Fig. 1).

Figure 1: Average price ($PPP) for smartphone plans with a volume allowance between 1GB and 5GB and unlimited voice minutes, year 2013



Note: The monthly all-inclusive price reflects the average price per month, including rebates and other fees, but excluding the cost of the device. Brazil, Greece and Turkey have been excluded from this figure because their data are inconsistent from year to year.
Source: FCC, 2015.

Our study draws on a rich dataset of the Federal Communications Commission (FCC) that contains 2,909 plans released by mobile network operators (MNOs) in 37 countries around the globe during the period 2011-2014. We construct a variable for the monthly price of each plan that includes activation costs, promotions and rebates. We then analyse the commercial strategy of mobile operators by estimating a price equation that takes into account several characteristics of the plans such as volume allowances (gigabytes), overage charges, download speeds, voice minutes allowances and the purchase of smartphones. We use multivariate regression techniques to study how operators design their plans. Specifically, we estimate the pricing equation by using ordinary least squares (OLS) and two stage least squares (2SLS). The instrumental estimation allows us treat for the potential endogeneity of mobile broadband penetration in the right hand side of the equation.

Consumers' heterogeneity in preferences over the broadband service, telephone calls and smartphones has resulted on a wide array of bundling strategies. Our analysis shows that operators use multi-tier pricing schemes to segment consumers according to their needs and their willingness to pay for data traffic (second degree price discrimination). They offer plans with different volume allowances and offer volume discounts to promote consumption. We show that an increase in one gigabyte in the data cap would have a positive impact of almost 10% on the monthly price paid by the customer, but plans with large volume allowances have lower prices per gigabyte.[52] Although most mobile plans limit data traffic to a few gigabytes, some operators also offer unlimited data plans at significantly higher prices to attract heavy users. Another dimension that differentiates the plans is the speed of the service. An increase of 10 Mbps in download speed implies an average 2% rise in prices. Interestingly, while in the case of fixed broadband plans the main segmentation strategy is the download speed, for mobile broadband plans the most relevant feature to segment consumers is the volume allowance.[53] This may be a consequence of the limitations that imposes the wireless technology.

---

[52] Cisco estimated that in 2012 the average data traffic for smartphones was 342 MB per month, although they expect a rapid increase in the next years. See *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017*, White Paper, February 2013.

[53] The ITU in its report "Measuring the Information Society 2013" analyses mobile broadband prices and mentions that data allowances are the main driver for mobile broadband plans.

In the case of volume metered plans, operators use different types of penalties for the consumers that exceed the contracted volume allowance. All consumers pay the same flat rate for the service up to the contracted data cap, and heavier users have to pay a penalty when they consume beyond the cap. The penalty can consist in a reduction in the speed of the service or in the interruption of the service until the next month. Quite often, however, consumers are switched to a new volume allowance or are billed an overage charge for each additional gigabyte consumed. We have found that all these types of penalties have similar effects in the monthly price paid by consumers, although in the case of monetary penalties heavy users have to pay a supplement when they exceed the data cap. Notice that these overage charges may cause unexpected high bills for consumers, either because they have a poor understanding of the pricing arrangements included in the contract or because they are unable to track how charges are accumulating under their plans.

Most plans bundle the broadband service with the telephone calls. We measure the effect of the inclusion of voice minutes in the price of the plan, although we are unable to observe if bundling reduces the prices of telephone calls compared to the plans that only offer the stand-alone voice service. It is worth mentioning that nowadays most operators use a tier scheme for telephone calls, instead of the pay-per-use schemes that were applied a few years ago. The plans do not distinguish between on-net and off-net calls, or between fixed-to-mobile and mobile-to-mobile calls. This reflects the change in the communication habits of the population, and might also be a consequence of the regulation of the termination charges.

Another contribution of the paper is to analyse the possibility given by operators to acquire a smartphone along with the contract of the broadband service. Operators offer consumers different options for financing smartphones: they can pay upfront the price of the smartphones at the beginning of the contract, or they can pay an extra charge in their monthly bill during the life of the contract. In the two cases consumers usually pay a lower price for the smartphone than if they were buying it directly from the manufacturer or from an independent dealer. In spite of this, our empirical model shows that the discounts offered by operators for the smartphones are partly compensated with a higher price paid for the broadband service. We also show that the monthly price for the broadband service is more expensive if consumers purchase iPhone and Samsung handsets. By contrast, the plans that bundle the broadband service with other handsets do not show a significant price difference with respect to only SIM plans. This result suggests that operators might use the brand of the smartphone to identify the consumers' willingness to pay for the broadband service (third degree price discrimination). Although this can also reflect the higher costs of these handsets or the lower bargaining power of operators in front of these manufacturers. Indeed, some operators have negotiated exclusivity contracts with handset manufacturers, which might result in higher prices for the broadband service in equilibrium.[54]

In the last part of the paper we examine if the structure of the mobile market and regulation have affected the prices set by operators. For this objective, we consider a sub-sample of 20 EU countries for which we have obtained information about the market characteristics from the European Commission Directorate General for Communications Networks (DG-CONNECT). Nowadays, in the EU the regulation determines the entry conditions of mobile virtual network operators (MVNOs) that use the spectrum of MNOs. Our analysis shows that the entry of MVNOs in national markets might have fostered MNOs to lower their tariffs. National regulators also regulate the termination prices (MTRs) that mobile operators charge to their rivals for terminating their telephone calls, but we do not find any evidence that this regulation has affected the retail prices. We explain that this can be a consequence of the new consumption patterns in the mobile market (transition from voice to data usage) and to the "glide-path" regulation applied to termination charges. Finally, we find that market concentration has a positive, but not significant, effect on broadband prices.

The structure of the rest of the paper is as follows. Section 2 reviews the economic literature that analyses the broadband market and the pricing strategies of operators. Section 3 outlines our estimation strategy. Section 4 describes the data set. Section 5 presents the empirical strategy and the results. Section 6 discusses the effects of competition and regulation on prices. Finally, Section 7 concludes.

[54] Exclusive contracts between mobile operators and smartphone manufacturers can soften price competition and pressure prices upward (Sinkinson, 2014). Examples of these types of contracts in the US are of the AT&T and iPhone exclusive contract between 2007 and 2011, and the exclusive contract between the first touch screen Blackberry with Verizon.

2. Literature review

Our research contributes to the empirical literature analysing broadband Internet prices in the telecommunications market. An important part of the literature on broadband Internet access has focused on the factors influencing the penetration of fixed broadband. Several papers have examined the effect of inter-platform and intra-platform competition in the adoption of fixed broadband (Distaso, Lupi and Manenti, 2006; Bouckaert, Van Dijk and Verboven, 2010; Pereira and Ribeiro, 2010; Briglauer, Ecker and Gugler, 2013; Gruber and Koutroumpis, 2013, Grzybowski and Dauvin, 2014). Other papers have analysed the effects of regulation of access charges and unbundling in the investment decision of fixed telecommunication operators (Grajek and Röller, 2012; Nardotto, Valletti and Verboven, 2014; Bacache, M., M. Bourreau and G. Gaudin, 2013).

The literature has devoted much less attention to examine the adoption of mobile broadband. Westlund and Bohlin (2008) analyse mobile Internet adoption and consumption in Sweden and show that user-friendliness and transmission speed are important determinants for the development of the service. Lee, Marcu and Lee (2011) employ a logistic diffusion model to analyse the drivers of broadband diffusion in a group of 26 OECD countries in the period 2003-2008. They find that standardization policies and population density are essential factors for the initial diffusion of the service. They also find that fixed and mobile broadband are complementary services in OECD countries. Srinuan, Srinuan and Bohlin (2012a) analyse the mobile internet access in Thailand using a binomial logit regression. The authors find that age, living area and availability of fixed telephony are amongst the significant drivers of mobile internet access. Finally, Srinuan, Srinuan and Bohlin (2012b) consider a panel data of Finish households in 2009, and using a multinomial logit model find that mobile Internet adoption is more likely among male, with a big family size that stays in renting apartment or in a cooperative apartment. They also explain that while xDSL customers do not perceive wireless technologies as a substitute, cable modem and fibre customers do so.[55]

[55] It is important to take into account that during the period of time considered in these studies mobile Internet services were at their infancy.

The analysis of broadband prices has also focussed in the fixed broadband service. Wallsten and Riso (2010) examine the prices of broadband plans in a group of 30 OECD countries between 2007 and 2009. They find that in this period downstream speed had a positive effect on prices, that plans with bit caps were on average cheaper than unlimited plans with contracts, and that plans with contracts were typically less expensive than those without. Greenstein and McDevitt (2011b) analyse the economic value created by the diffusion of broadband Internet access provided via xDSL and cable modem in the United States. They do not have direct information on prices, but create a price index that adjusts the price to the progressive improvement in service quality between 2004 and 2009. Calzada and Martínez-Santos (2014) analyse the determinants of broadband Internet access prices in a group of 15 EU countries between 2008 and 2011. They find that downstream speed had a positive effect on prices, and that cable modem and fibre technologies were available at lower prices per Mbps than xDSL technology. They also show the effects of bundling and volume caps. On the other hand, the paper shows that in the period examined broadband prices were higher in countries where entrants made greater use of bitstream access and lower in countries where there was an intensive use of local loop unbundling. Yet, very few papers have analysed mobile broadband prices. Srinuan, Srinuan and Bohlin (2013) examine the prices of wireless communications in Thailand and show the role of demand characteristics in the development of new plans. On the other hand, Haucap et al. (2014) analyse the effect of tariff diversity on broadband uptake using a dataset of fixed and mobile broadband plans via USB modem devices. They find that low prices, higher incomes and the diversity of plans are important drivers for broadband adoption. To our knowledge, our paper is the first empirical work that examines the design of mobile broadband plans for smartphones.

In the last years, a number of theoretical papers that have been elaborated are very useful to understand the pricing strategy of mobile operators. There is an important literature analysing profit and welfare maximizing pricing structures (Tirole, 1988; and Wilson, 1993). A basic assumption of these papers is that consumers are rational decision makers that choose the tariff that maximize their surplus, but that the pricing structure does not influence their choice. Some papers have also considered how demand uncertainty affects the selection of contracts by consumers (Lambrecht, Seim and Skiera, 2007). In recent years, a new strand of the literature has analysed how the pricing structures established by operators can affect consumers' usage decisions and transform the utility offered by firms (Bertini and Wathieu, 2008; Ascarza, Lambrecht and Vilcassim, 2009; and Leider and Sahin, 2014). The underlying assumption in these models is that consumers make mistakes while taking their decisions because they are uncertain about how much they will consume the service and about the utility they can obtain. In this context, it can be shown that the pricing structures influence the types of mistakes consumers make. For example, some papers have shown that consumers exhibit a biased preference for choosing unlimited usage plans over pay-per use contracts, which can be related to risk aversion, demand over-estimation, and distaste for paying per consumption (Lambrecht and Malmendier, 2006).

Other recent papers have examined the interaction between mobile operators and other agents that intervene in the telecommunications market such as content providers and smartphones manufactures. Economides and Hermalin (2014) analyse the reasons that make carriers to commercialize volume metered plans. Traditional responses are that volume caps are part of a second-degree price discrimination scheme via quantity discounts and that they alleviate congestion externalities. But these authors identify a third reason for their use: with volume caps competition among content providers increase and they are more likely to lower their prices to attract consumers. When this happens, telecommunication operators can increase their prices to capture the increase in the consumers' surplus. In other words, volume caps allow ISPs to capture the surplus created by content providers. Another group of papers have analysed the effect of exclusive contracts with handset manufacturers. Exclusive contracts restrict manufacturers from engaging in trade with competing operators and for this reason they must be compensated for the loss of potential market. Exclusive contracts increase the prices of the plans that bundle the broadband service with the smartphones, and if prices are strategic complements they also increase the prices of the rest of smartphones. From the consumers' perspective, exclusivity increases prices and reduces the variety of handsets. Zhu, Liu and Chintagunta (2011) examine the welfare effects of Apple's exclusivity. On the other hand, Sinkinson (2014) analyses the effects of exclusive contracts for smartphones using a monthly market-level dataset of US consumers for the period 2008-2010. The paper proposes that the existence of exclusivity may respond to the relative market power of handset manufacturers versus mobile operators. Exclusivity can be a profit-maximizing strategy as consumers are more price sensitive with respect to wireless networks than handsets.

3. Empirical model

We examine the prices of mobile broadband using a dataset containing information of 2,909 plans collected by the FCC between 2011 and 2014 in 37 countries. The paper focuses in the plans offered by MNOs because the FCC only collects information for this type of operators. On the other hand, we only consider the plans for smartphones, although operators also commercialize broadband services for laptops and tablets (big screen devices) connected via a USB modem or a MiFi (wireless router).[56] Nowadays the use of mobile broadband through smartphones is much more popular than through USB modems. In 2013 the EU-27 average penetration of mobile broadband for smartphone was 42.8% compared to 11.3% of mobile broadband for a laptop/tablet. Moreover, smartphones can be used as a modem in the same way as a USB plan (by using the 'tethering' application), allowing the access to Internet through other devices such as laptops.

The aim of the next sections is to analyse how operators design their tariffs in order to increase their customer base and extract the maximum surplus from them. We want to estimate a model for the monthly price of mobile broadband plans, P_{moit}, where m is the plan offered by the operator, o is the operator, i is the country, and t is the time. The pricing equation includes several variables to analyse the operators' multi-tier schemes and some variables that describe the characteristics of the operators. Country and year fixed effects δ_i and η_i are included to control for unobserved heterogeneity across countries and years. On the other hand, e_{moit} represents the disturbance term.

Pricing model (1):

$$\begin{aligned} Log(\text{Price}_{moit}) = {} & a_0 + a_1\text{LimitedData}_{moit} + a_2\text{Penalty}_{moit} + a_3\text{Volume}_{moit} + a_4\text{Volume}^2_{moit} + a_5\text{Speed}_{moit} + a_6\text{Technology}_{moit} \\ & + a_7\text{LimtedVoice}_{moit} + a_8\text{MinVoice}_{moit} + a_9\text{Historical}_{mot} + a_{10}\text{NPlans}_{mot} + a_{11}\text{Penetration}_{it} + \delta_i + \eta_t + e_{moit} \end{aligned}$$

[56] The FCC classifies mobile broadband offers according to the device: smartphone, tablet or stick modem.

The prices of the plans included in the model are the average monthly prices paid by consumers during the period they stay with the operator. The main bulk of these prices is the monthly tariff, but we also take into account temporary monthly promotion at the beginning of the contract, rebates (refunds) and non-recurring costs such as activation fees. We consider the total access cost customers bear during the life of the contract. Equation (2) shows that the monthly price is constructed as the sum of the promotional tariff paid during the months of the promotion plus the regular tariff paid during the remaining months in which the consumer is expected to stay with the operator, plus activation costs, non-recurring costs paid at the beginning of the contract, minus rebates. This quantity is divided by 36, which is the expected number of months that consumers will stay with the operator.[57] The European Commission establishes that the maximum duration for a contract is 24 months, but in some countries of our sample there are plans of 36 months. It is also important to mention that the activations costs and rebates are a very small part of the total costs borne by the customer when they consume mobile broadband services. For this reason, the results of our analysis do not vary much if we consider other permanence periods such as 24 or 48 months.

Price equation (2):

$$\text{Price}_{\text{moit}} = \frac{\text{Promo.} * \text{Months Promo} + \text{Tariff} * (\text{Months without Promo}) + \text{ Fees - Rebates}}{\text{Contract Duration}}$$

In order to examine the operators' pricing structure we consider that they commercialize unlimited usage contracts and three-part tariffs. In the later case, the tariff includes an access fee, a usage allowance (number of GB that consumers can use for free), and a penalty system for the case in which consumers exceed the contracted allowance.[58] In order to reflect these

[57] In the case of fixed broadband plans, the average duration of the contracts in the EU is 26 months according to the European Commission (2011). Also note that non-recurring costs in mobile plans are usually much smaller than those of fixed broadband plans, which might include installation costs and the payment of a router.

[58] According to Lyons (2013), in the US three-tiered pricing plans were introduced by AT&T in December 2010. These plans establish some volume allowances and a per-gigabyte overage charge. Verizon Wireless adopted a similar pricing scheme in 2011. T-Mobile, by contrast, does not set an overage charge on customers who exceed the cap, but reduces the speed of the service for the rest of the month. Finally, Sprint commercializes unlimited data plans at a flat rate.

options, we use the dummy variable *LimitedData*, which distinguishes between usage based and unlimited usage plans. This variable equals one for three part tariffs (limited usage) and cero otherwise.

For a number of usage based plans we have information about the penalties applied to the consumers that exceed the volume allowance. The penalties can be either 'overage charges' in the form of pay-per-unit charges (for megabyte) or can force consumers to switch to a new usage allowance. They can also imply the reduction in the speed or even the interruption of the service until the beginning of the next month. We have created four dummy variables that identify the use of these penalties. In some specifications of the model, we substitute the variable *LimitedData* for them. *EndService* means that the consumer cannot longer use Internet when the allowance is exceeded. This option is used in some countries like Belgium or Korea but has a small prevalence in our data set. *SpeedReduction* represents the case where the speed of the service is reduced to very low download speeds (e.g.: 128 kpbs) when the volume allowance is exhausted. This situation might prevent consumers from using some applications that require higher speeds, such as watching videos. *Pay-as-you-go* is a penalty that forces consumers to pay a per-unit of volume (megabyte/kilobyte) when they exceed the allowance contracted. Some operators charge a per-unit of time (hour or day), but this is something quite infrequent. Finally, *New Allowance* reflects the case where consumers are moved to a new allowance, which allows then to use a larger number of gigabytes, but at a higher price. Note that both *Pay-as-you-go* and *New Allowance* are 'overage charges' and might cause an unexpected increase in the bill paid by consumers ('bill shock'). This can occur when consumers have a poor understanding of the conditions of their contracts or when they are unaware of the volume they have consumed. Operators can also hide these overage charges so as to charge a higher bill (Gabaix and Laibson, 2006). Our data set only contents the information included in the operators' plans and therefore we can't determine the impact that overage charges have on the final bill paid by consumers. In spite of this, we can examine how the design of the plans affects the monthly prices.

In the case of three part tariffs, the variable *Volume* is defined as the volume allowance (in gigabytes) specified in the plan. Volume caps are introduced in the price equation in a non-linear way, since we expect that the price per unit of volume (gigabytes) will decrease with the allowance. An important part of the plans of our dataset include volume allowances that restrict the data that can be downloaded by consumers in each month. As we have mentioned before, the use of limited usage plans might respond to different reasons. They can be considered as a second degree price discrimination mechanism that allows charging higher prices to consumers that are willing to pay more for the service. Specifically, it allows segmenting consumers according to the intensity in the use of the service. Volume caps can also help operators to optimize the use of the network and to reduce congestion due to high usage. Finally, Economides and Hermalin (2014) have shown that operators can also use volume caps to appropriate surplus from upstream content providers. According to them, operators can gain from volume caps through the following mechanisms: if volume caps are binding (*EndService*, *SpeedReduction*) consumers will perceive contents and applications as substitutes. This will increase the competitive pressures on the content providers, who will respond by lowering their prices. In this case, operators can capture the surplus gained by consumers via higher prices of their plans. If caps are permeable (*Pay-as-you-go, New Allowance*), then the cap acts as a disguised two-part tariffs and the additional fee charged by operators' acts as an excise tax that leads the content providers to cut their prices.

The prices might reflect others aspects that affect the quality of the service. *DownloadSpeed* is the maximum speed that can take the broadband service according to the information announced by operators in their web sites. Speed tiers segment consumers taking into account their willingness to pay for quality and for the possibility of using some applications. A high speed allows using advanced services such as on-line gaming and video conferencing. Note, however, that many mobile operators do not announce the download speeds of their plans. This might be because most MNOs use the same technology or because they can't guarantee the quality of the service.[59] In the case of fixed broadband plans, by contrast, operators use different provision technologies (xDSL, cable and fibre) and can price discriminate consumers taking into account the speed offered. These operators also establish volume allowances, but this is not the main determinant of their prices (Calzada and Martínez-Santos, 2014).

[59] According to the FCC (2015), advertising about the speed vary widely across countries. Some operators in countries such as Hong Kong, Italy and Poland, advertise the theoretical maximum available speeds (i.e. they report 100 Mbps for 4G and 42.2 Mbps for 3G HSPA+). In contrast, the highest speed advertised for a 4G plan in the United States is 5-12 Mbps and for a 3G plan it is 7.2 Mbps.

The main factor explaining the download speed is the transmission technology. For each generation of mobile telephony the International Telecommunications Union (ITU) has approved technological standards that have to meet a number of technical requirements, for example regarding the download speed or the latency of the service. In the period we analyse, mobile operators used several standards such as WCDMA, UMTS, HSPA and LTE. We have grouped these standards according to 3G, 3.5/3.75G, and 4G technologies and we have created a dummy variable for each of them.[60] We use these *Technology* variables to analyse if operators have been able to charge higher prices for 4G plans than for the previous technologies, or if competition has been sufficiently intense as to force them to upgrade the quality of the service at no extra cost.[61] For instance, in the UK the operator *Three* decided to offer 4G plans at the same price as 3G plans and this put competitive pressure on the other operators. In Spain, Vodafone was the first operator to offer 4G and initially it charged higher prices for this service, but it quickly eliminated the price difference between 3G and 4G plans when its competitors started to offer the same product.

Many plans combine data allowances with voice minutes and/or text messages allowances. The popularization of smartphones has modified importantly the way in which the population communicates and nowadays an important part of the wireless traffic is generated by Internet contents and applications. Moreover, a part of the voice traffic has been substituted by applications like *WhatsApp* or *Line* for messages and *Skype* for voice. Operators have reacted to this situation by modifying the way they bill telephone calls. Some plans offers exclusively mobile broadband, but most of them also include voice minutes and/or text messages allowances. We reflect this situation in our model by including the dummy variable *LimitedVoice,* which takes value one if the plan includes voice minutes allowances and zero if the plan includes unlimited phone calls. For those plans with voice minutes allowances, the variable *MinutesVoice* reflects the minutes cap. According to the FCC (2015), in some countries operators may use phone calls to cross-subsidize their data plans. Unfortunately, we can't identify this strategy because we do not have information about the plans that only offer telephone calls, but we can measure the impact of the inclusion of voice minutes allowances on the price

[60] The FCC dataset has less than ten plans that use 1G or 2G technologies. We do not consider these in our analysis.

[61] OFCOM (2014) compares the performance of 3G and 4G networks in the UK. It presents a general analysis and also compares the service offered by the mobile networks.

of the plans.

Another interesting feature of our dataset is that it allows identifying if the plan only offers a SIM card or if it also includes the purchase of a smartphone. The consumers that purchase the smartphone from the mobile operator usually have to choose between paying the smartphone at the beginning of the contract or paying an additional fee during the life of the contract. In order to know how the purchase of the smartphone affects the price of the service we include several dummy variables in the pricing equation. Specifically, we have introduced four dummies for *Smartphone* in our model. One of the dummies represent only SIM card plans and the three other show if the plan includes an iPhone, a Samsung, or other smartphone brands (Nokia, HTC, Blackberry, Sony, etc.), which are much less representative in our dataset and less demanded worldwide by consumers.[62]

The effect that the inclusion of the smartphone has on the price of the plan is unclear. As a matter of fact, mobile operators provide smartphones to millions of consumers and some operators are present in several countries. This should give them some bargaining power in front of manufacturers and they may be able to negotiate discounts in the prices. If there is enough competition in the market these discounts should be passed-through to the consumers. In spite of this, smartphones are a differentiated product and some of them are more sophisticated and expensive than others. Taking this into account, operators can use smartphones to identify consumers with a higher willingness to pay for the service and can charge them a higher monthly tariff.

The monthly price of the service is also related with the duration of the contract. The variable *DurationContract* represents the length in months of the contract subscribed by the customer. Operators might be keen to reduce the monthly price of the service when customers engage for longer periods of time. Also, the duration of the contract is related with the acquisition of a smartphone. Operators tie consumers to long contracts when the price of the smartphone is paid through the monthly bill, and consumers have to pay a penalization if they abandon the plan before the contract expires. Hence, we expect that the duration of the contract should have a negative effect in the price, and we also expect that the variables *Smartphone* and *DurationContract* will

[62] According to IDC Worldwide Quarterly Mobile Phone Tracker, in the fourth quarter of 2014 the 28.9% of mobile phones shipped were Samsung and 17.5% were iPhone.

be correlated.

We still consider another group of control variables that can affect the level of prices and the structure of the tariffs set by operators. The variable *Nplans* is the number of plans released by all MNOs in the year in which the information was collected. The effect of the number of plans on the price is ambiguous. On the one hand, operators might release a large number of plans to price discriminate consumers or to generate confusion or misunderstandings (Hoerning, 2001). But on the other hand, the release of more plans can also reflect the intensity of competition. For instance, the entry of MVNOs might foster MNOs to release specific plans for low income/lighter consumers in order to fight competitors (Calzada and Martínez-Santos, 2014). *HistoricalOperator* is a dummy that takes value one when the operator that commercializes the plan is the incumbent firm in the country (or the first historic mobile operator). Mobile operators that entered the market at the end of the nineties acquired an important presence in the market and have been able to build a reputation in front of consumers. We want to know if this "first mover advantage" has a persistent effect in the prices or if the strengthening of competition and the arrival of MVNOs has dissipated it.

Finally, our empirical model also includes the level of penetration of mobile broadband in the country. Specifically, *Penetration* is defined as the percentage of mobile broadband lines in each country. Unfortunately we do not hold data on the number of subscribers to each plan, nor on the number of lines per operator. Nevertheless, we expect that a large penetration level in a country should have a negative effect on prices due to the presence of scale and scope economies and to the intensification of competition in mature markets. It is important to take into account that lower prices could also have a positive effect on service adoption. This generates a potential endogeneity problem that we try to solve by estimating our pricing model with two-stage least squares estimation.

4. The data

Information about mobile broadband plans has been obtained from the "International Broadband Data Report" of the Federal Communications

Commission (FCC).[63] The dataset contains 2,909 residential retail mobile broadband plans for smartphones collected from 37 countries around the globe, including all OECD countries.[64] In total, the assembled dataset include 579 plans for 2011, 1,102 plans for 2012, 429 for 2013 and 799 for 2014.[65] Information about the level of fixed and mobile broadband penetration, usage of Internet and other indicators about the broadband sector have been obtained from the "Measuring the Information Society" report of the International Telecommunications Union (ITU). The European Commission Directorate General for Communications Networks, Content & Technology (DG-CONNECT) publishes information about the regulation of the mobile markets and the measures of the competition level in the EU-28. Finally, Eurostat, the World Bank and the International Monetary Fund (IMF) have information about socio-demographic variables, exchange rates and power parity indexes.

We have obtained information about the prices and the characteristics of the plans from the FCC dataset. The FCC has obtained this information through the operators' websites, but operators might offer different plans and promotions through other sale channels aside from the Internet. All retail broadband prices are converted to US dollars using the Purchasing Power Parities (PPP) currency conversions published by the World Bank to facilitate comparability.[66] Over the life of a contract, customers pay recurring costs (the monthly tariff) and other non-recurring fees, such as activation costs paid at the beginning of the contract,[67] promotions and rebates applied to the bill.[68] The prices used in our analysis do not include the device price that accompanies the costs of the plan (data, voice and SMS). Hence, if a plan includes the cost of the device into the monthly charge, the price for the

---

[63] Our dataset has used the third and fourth releases of the FCC report. See: http://www.fcc.gov/document/fourth-international-broadband-data-report-2015.

[64] The original dataset contains information for 40 countries (including all OECD countries) but the FCC signals in the methodology of its "Fourth International Broadband Data Report" that data for Greece, Brazil, and Turkey is inconsistent from year to year. For this reason, we do not use information for these countries.

[65] There are 90 plans with contract duration of less than one month that have not been included in our analysis. Also, the information for some plans presents missing values for the tariffs and for some other relevant characteristics.

[66] Similar results are obtained when we do not use this transformation.

[67] Non-recurring costs in the mobile sector are much smaller than in the fixed broadband services, where consumers may need to pay an installation costs and the payment of a router.

[68] Some operators use promotions that increase the usage limits. This measure modifies the price of the offer.

service will appear to be more expensive than a plan that charges the customer a flat fee upfront for the device. Table 1 shows some basic statistics of the main components of the prices and of the plans. Around 85% of the plans considered in the analysis bundle several services such as Internet, telephone calls and texts messages.[69] Most plans are volume metered: only 10% of the plans offer unlimited volume allowances and around 30% of bundled plans have unlimited minutes of telephone calls.

Table 2 summarizes the characteristics of the plans offered in each country during the period 2013-2014. In this period, only operators in 8 countries offered unlimited data plans, while in the period 2011-2012 there were 17. On the other hand, in the last years there has been an increase in the volume allowances. While in the period 2011-2012 the average volume allowance was around 2.5 GB, in the 2013-2014 it increased to 4 GB. Finland is the country with the highest number of unlimited plans (71% out of the total) and Sweden is the country with the plan with the highest data allowance (80 GB). Moreover, the number of telephone calls in plans with limited voice caps has more than doubled on average since 2011 and has reached around one thousand minutes in 2014. However, the average prices in our sample have stayed constant across the study period at around $50 ($PPP).

Table 1: Summary statistics FCC dataset of mobile broadband plans (37 countries)

Variable	Number of plans	Average	Standard deviation	Minimum	Maximum
Price ($PPP)*	2909	48.6	37.1	0.4	271.2
Monthly tariff ($PPP)	2909	50.0	37.4	1.1	271.2
Monthly promotion ($PPP)	2909	4.8	17.8	0.0	215.0
Activation costs ($PPP)	2909	6.6	16.3	0.0	225.1
Rebate ($PPP)	2909	8.7	51.1	0.0	449.0
Highest download speed (Mbps)	2126	30.1	36.1	0.1	150.0
Volume allowance (GB)**	2579	3.5	6.4	0.0	80.0
Voice allowance (minutes)***	1448	663	1434	0	10000
Contract duration (months)	2717	18.5	8.0	1	36

* Price is defined as the monthly price paid by a customer that stays 36 months with the operator (see calculation of price in section 3).

** There are 209 plans with unlimited data.

*** There are 794 bundles with unlimited minutes and 259 plans that do not include minutes allowances.

[69] The dataset does not include multi-play plans which combine fixed and mobile services.

The penalties faced by consumers when they exceed the contracted data allowance vary importantly across countries.[70] Table 3 shows that in many countries such as Bulgaria, Spain, Hungary, Denmark, Germany, Sweden or Austria operators frequently use speed reductions (the speed is usually reduced to 56/128 kpbs). By contrast, in New Zealand, Australia, Lithuania, Slovenia, Norway or India it is much frequent that consumers jump to pay-as-you-go. In this case, some operators charge per unit of volume (megabyte/kilobyte) and in a very few cases operators charge per unit of time (hour or day). Finally, in Iceland, United Kingdom, Mexico, Singapore, Canada, the Netherlands or Japan consumers are automatically changed to a new allowance (they contract a larger number of GB).

Many plans offer consumers the possibility to buy a smartphone in addition to contract the SIM card. Table 4 shows for each country the percentage of plans that include a smartphone, which can be an iPhone, a Samsung or another brand (Blackberry, Nokia, HTC, LG, Sony, etc). In the data set there are several countries were operators do not offer SIM only plans. Also notice that a large percentage of plans include an iPhone or a Samsung.

The length of the contract is usually related to the type of smartphone included in the offer. Table 5 shows that while SIM-only contracts last on average 16 months, contracts providing an iPhone or a Samsung last 20 months, and contracts for Other Brands last on average 18 months. The median duration of the contracts is even shorter for SIM-only plans compared to smartphone plans, 12 versus 24 months.

[70] In the case of unlimited data plans, there might be penalizations when customer makes a too intensive or inappropriate use of the service (fair usage policy). We do not analyse this situation.

Table 2: Mobile broadband Plans 2013/2014. Average values of characteristics by country

	Number of plans	Number of mobile operators	Price ($PPP)*	Monthly tariff ($PPP)	Maximum download speed (Mbps)	Ratio 4G plans over 3G (%)	Unlimited data plans (%)	Volume cap (GB)	Bundled plans with minutes of voice (%)	Bundles with unlimited minutes (%)	Voice cap (minutes)
Australia	20	2	44.3	44.3	15.4	50.0	0.0	2.5	100.0	60.0	427.3
Austria	18	3	42.2	41.2	26.6	100.0	5.6	3.2	100.0	44.4	1300.0
Belgium	30	4	42.9	43.8	38.0	100.0	0.0	2.4	100.0	70.0	197.6
Bulgaria	19	3	42.4	42.4	42.0	0.0	0.0	1.3	100.0	100.0	1600.5
Canada	74	3	34.0	35.3	131.8	100.0	0.0	5.1	100.0	0.0	-
Chile	20	3	129.3	129.3	9.2	50.0	0.0	4.4	100.0	100.0	666.0
Czech Republic	69	3	52.2	52.2	74.9	100.0	0.0	2.9	100.0	0.0	-
Denmark	37	3	21.8	21.7	66.9	91.9	0.0	4.8	100.0	42.4	203.6
Estonia	9	2	26.8	26.8	35.3	33.3	0.0	8.4	100.0	87.5	411.4
Finland	7	3	16.3	16.3	37.4	42.9	71.4	0.2	42.9	100.0	42.9
France	62	4	49.2	49.8	87.1	93.5	0.0	4.0	100.0	25.8	120.0
Germany	44	3	61.3	61.0	45.2	90.9	0.0	4.8	100.0	27.3	125.0
Hong Kong	34	5	49.7	49.7	31.2	52.9	21.9	3.1	100.0	89.7	2007.7
Hungary	14	2	62.4	62.4	76.2	64.3	0.0	1.1	85.7	64.3	190.0
Iceland	17	2	32.4	32.4	14.9	47.1	0.0	3.0	100.0	60.0	122.2
India	51	4	39.1	40.8	21.5	11.8	0.0	3.9	100.0	100.0	6965.7
Ireland	39	3	54.4	54.4	21.0	25.6	0.0	4.1	100.0	69.2	298.1
Israel	5	2	21.1	21.1	4.0	0.0	0.0	3.0	100.0	20.0	300.0
Italy	28	4	41.3	44.5	52.5	32.1	3.6	2.3	100.0	50.0	347.7
Japan	17	3	32.2	32.2	75.0	92.3	37.5	4.4	-	-	-
Korea (South)	16	3	47.5	47.5	-	100.0	0.0	2.2	100.0	100.0	110.0
Lithuania	23	3	9.1	8.9	18.0	0.0	0.0	1.3	100.0	92.3	730.0
Luxembourg	9	3	8.0	17.8	29.5	66.7	0.0	12.4	100.0	100.0	86.7
Mexico	29	2	69.9	69.9	18.4	100.0	0.0	1.7	100.0	100.0	566.9
New Zealand	19	1	53.5	53.5	7.2	26.3	0.0	1.4	100.0	68.4	336.9
Norway	13	1	35.2	35.2	19.4	100.0	0.0	2.2	100.0	0.0	-
Poland	39	3	36.3	36.3	-	12.8	0.0	1.3	100.0	57.7	400.0
Portugal	17	3	54.2	54.5	39.0	70.6	17.6	1.3	82.4	70.6	909.2
Singapore	20	3	87.6	87.5	86.6	100.0	0.0	5.4	100.0	80.0	377.5
Slovakia	6	3	48.4	48.4	33.8	33.3	0.0	1.6	100.0	33.3	125.0
Slovenia	37	4	10.3	20.1	42.0	13.9	0.0	1.9	100.0	100.0	598.5
Spain	29	5	40.0	43.7	9.0	58.6	0.0	1.4	88.9	66.7	172.2
Sweden	39	3	42.1	42.0	42.6	53.8	0.0	8.7	28.6	100.0	626.2
Switzerland	11	3	22.7	27.4	100.0	100.0	0.0	4.1	37.5	100.0	22.5
The Netherlands	32	4	54.6	64.8	30.4	81.3	0.0	1.9	96.9	71.9	189.1
United Kingdom	22	5	52.2	52.8	-	36.4	18.2	3.5	100.0	31.8	1014.3
United States	161	7	84.1	85.8	17.4	99.4	3.7	8.2	100.0	0.0	-

* Price is defined as the monthly price paid by a customer that stays 36 months with the operator (see calculation of price in section 3).

Table 3: Internet usage penalties by country

	Number of plans	No penalization (unlimited plans)	Speed reduction	Jump to pay as you go	Jump to new allowance	End of service
Australia	82	0%	0%	91%	9%	0%
Austria	40	3%	85%	0%	10%	3%
Belgium	49	2%	24%	49%	0%	24%
Bulgaria	62	0%	100%	0%	0%	0%
Canada	93	0%	0%	47%	53%	0%
Chile	37	3%	59%	30%	8%	0%
Czech Republic	26	0%	65%	0%	35%	0%
Denmark	54	0%	89%	4%	7%	0%
Estonia	21	29%	71%	0%	0%	0%
Finland	21	52%	48%	0%	0%	0%
France	136	0%	76%	3%	21%	0%
Germany	68	10%	88%	1%	0%	0%
Hong Kong	80	39%	15%	34%	13%	0%
Hungary	57	2%	93%	0%	5%	0%
Iceland	29	0%	0%	14%	86%	0%
India	76	0%	24%	68%	8%	0%
Ireland	103	15%	6%	50%	29%	0%
Israel	1	0%	0%	0%	0%	100%
Italy	57	16%	35%	11%	39%	0%
Japan	56	29%	14%	11%	46%	0%
Korea (South)	141	17%	0%	60%	0%	23%
Lithuania	59	5%	0%	86%	8%	0%
Luxembourg	39	5%	10%	67%	18%	0%
Mexico	64	0%	6%	20%	70%	3%
New Zealand	62	0%	0%	97%	3%	0%
Norway	33	0%	30%	70%	0%	0%
Poland	55	5%	84%	7%	4%	0%
Portugal	33	18%	6%	52%	24%	0%
Singapore	38	0%	24%	16%	61%	0%
Slovakia	24	29%	63%	8%	0%	0%
Slovenia	65	0%	14%	71%	15%	0%
Spain	84	2%	98%	0%	0%	0%
Sweden	65	9%	86%	0%	5%	0%
Switzerland	54	37%	41%	20%	2%	0%
The Netherlands	85	0%	24%	27%	49%	0%
United Kingdom	84	15%	5%	0%	80%	0%
United States	273	9%	29%	17%	42%	4%
Total	2,406	9%	36%	30%	23%	2%

Table 4: Summary of contract duration (months) for SIM only plans and by smartphone brand

	Number of plans	Average contract (months)	Median contract (months)	Minimum contract (months)	Maximun contract (months)
SIM only	238	16.5	12	1	36
iPhone	1,029	19.1	24	1	36
Samsung	705	19.4	24	1	36
Other brands	590	18.0	24	1	36
Total	2,562	18.7	24	1	36

Table 5: Summary of SIM-only and plans with a smartphone by country

	Number of plans	SIM only plans (%)	Plan includes an iPhone (%)	Plan includes a Samsung (%)	Plan includes Other brands (%)	Average contract duration
Australia	80	26%	68%	0%	6%	19
Austria	40	28%	60%	0%	13%	24
Belgium	44	39%	30%	18%	14%	12
Bulgaria	42	12%	21%	67%	0%	18
Canada	93	8%	52%	33%	8%	18
Chile	40	3%	85%	13%	0%	17
Czech Republic	93	0%	23%	70%	8%	19
Denmark	58	0%	86%	0%	14%	17
Estonia	24	17%	0%	75%	8%	24
Finland	21	0%	76%	0%	24%	21
France	186	9%	31%	16%	45%	19
Germany	76	0%	47%	32%	21%	23
Hong Kong	77	22%	32%	21%	25%	19
Hungary	60	2%	32%	32%	35%	24
Iceland	34	0%	65%	35%	0%	11
India	75	9%	11%	11%	69%	10
Ireland	139	4%	27%	19%	50%	14
Israel	16	0%	38%	25%	38%	13
Italy	71	10%	39%	34%	17%	22
Japan	32	0%	78%	22%	0%	24
Korea (South)	97	45%	14%	32%	8%	23
Lithuania	52	2%	52%	25%	21%	23
Luxembourg	30	17%	30%	10%	43%	19
Mexico	60	0%	67%	12%	22%	19
New Zealand	62	5%	58%	11%	26%	18
Norway	33	0%	73%	0%	27%	12
Poland	71	0%	13%	44%	44%	21
Portugal	40	0%	75%	0%	25%	16
Singapore	32	13%	28%	47%	13%	24
Slovakia	24	17%	25%	21%	38%	19
Slovenia	97	13%	10%	64%	12%	22
Spain	89	11%	46%	11%	31%	22
Sweden	89	3%	79%	7%	11%	18
Switzerland	62	19%	63%	5%	13%	15
The Netherlands	111	14%	24%	50%	12%	20
United Kingdom	105	5%	35%	21%	39%	23
United States	275	0%	40%	46%	14%	14
Total	2,630	9%	41%	27%	23%	19

5. Estimation and Results

This section presents the econometric model that we use to analyse how mobile operators set their prices. We first estimate the pricing equation in (1) using OLS. Notice that this estimation might be affected by the potential endogeneity of the variable *Penetration* since the causality between prices and mobile broadband take-up should be bidirectional. One way to address this problem is to use the 2SLS-IV approach. To do this, we need some instruments that are correlated with the variable penetration but that do not affect the prices of the plans other than indirectly through its impact on penetration. Our candidates to instrument *Penetration* are the variables

Education, *Gross Domestic Product* (*GDP*) and *Percentage of Household with a Computer* (*PC*): Information for *Education* has been obtained from the UNESCO Institute for Statistics (UIS) and it is defined as the percentage of inhabitants with tertiary education skills (at least a bachelor degree).[71] This variable is expected to have a positive impact on the adoption of mobile Internet as high skilled individuals should be able and more interested on the mobile Internet while these skills should not impact on the prices; *GDP* has been collected from the IMF and represents the gross domestic product per capita in dollars and adjusted by the purchasing power parity ($PPP) in each country. We expect that people living in countries with a higher GDP per capita should be more likely to contract mobile broadband Internet. Finally, *PC* is the percentage of households in the country that have a computer. This variable should be positively correlated with Internet adoption, but not with the price of wireless broadband plans.

We have verified that the selected instruments are valid to solve the endogeneity problem. Specifically, we have found that they pass the Hansen's J test for over identifying restrictions. Moreover, we have considered the instruments suitability test (first stage F-statistic of the variable *Penetration* over the socioeconomic instruments) to measure the strength of our instruments. We have also analysed other instruments such as the population density and the unemployment rate in each country but we have found that the best set of instruments that fulfill the orthogonality condition are the ones described above.

Table 6 shows the reduced form regressions for the pricing equation when the whole sample of countries is considered. We present four specifications for the OLS estimates and three for 2SLS estimates. Most of the results obtained are in line with the hypothesis that we have formulated in the previous section and they are robust to different specifications of the model. The coefficient of the variable *Penetration* is not significant in any case, but while the sign in the OLS specifications is positive it takes negative values in the 2SLS regression. The lack of significance of this variable might be due to the fact that it considers the penetration of the service at the country level and not the number of subscribers to each plan. This situation might soften the causality effect between penetration and price.

[71] Note that the variable Penetration is defined at the country level and for this reason it could be a collinearity problem between this variable and the country fixed effect.

The variable *LimitedData* (*Volume Allowances*) shows that usage-based plans are substantially cheaper than unlimited plans. The magnitude of the coefficients in specifications 3 and 5 are quite similar, although with 2SLS the coefficient is a bit smaller. As we have explained before, volume caps act as a second price discrimination mechanism to extract consumer surplus and to avoid congestion. This price design allows lighter consumers to pay less for the service than with unlimited data plans.

Mobile operators can establish different types of penalizations in the plans that include volume allowances. The penalties are applied to the consumers that exceed the number of gigabytes specified in their plan, and can consist in a quality reduction or in an overage charge. In specifications 4, 6 and 7 we have disaggregated the variable *LimitedData* in four dummy variables that reflect the type of *Penalty* that can suffer the consumers. In all the specifications the dummies have negative and significant coefficients, meaning that usage based plans are always cheaper than unlimited plans. *SpeedReduction* is the penalty that has a smaller impact on the price of the plans. Recall that in this case, consumers are still able to use the services and applications that require low speeds such as e-mails and other instant messaging services. The penalties that force consumers to switch to *pay-as-you-go* or to a *new allowance* have a similar impact on the monthly tariff as *SpeedReduction*, although in this case consumers have to incur in an additional fee that we can't observe. Finally, plans that imply the end of service are the cheapest, although in our sample these plans are the most uncommon and are used only in a few countries (basically Belgium and South Korea).

The variables *Volume* and *Volume*^{2} reflect the impact of volume caps on usage-based plans. The coefficients of these variables are significant in all specifications and have the expected sign. The coefficient of the variable *Volume* shows that an increase in one additional gigabyte in the cap would have a positive impact of almost 10% on the monthly price paid by the customer (specifications 4 and 7). On the other hand, the negative coefficient of *Volume*^{2} shows that operators apply volume discounts.

Regarding the technology, only the variable *4G* is significant in specifications 1, 2 and 7. This might indicate that operators are better able to set high prices by announcing high speeds than by announcing the use of a new wireless technology. Indeed, the comparison of specifications 6 and 7 show that

Technology losses its significance when *Speed* is included in the model. Operators might not be able to charge a premium for 4G plans when other operators also offer them. In specification 2 to 6 the coefficient for *Speed* is positive and significant, showing that prices increase with the quality of the service. The coefficient of *Speed* should be interpreted in the sense that an increase of 10 Mbps in the download speed increases the price of the plan by around 2%.[72] Notice that the inclusion of *Speed* in the model produces an important reduction in the number of observations because quite often operators do not mention the speed of the plans in their web sites. In spite of this, we have included this variable in our analysis because it is a relevant characteristic of the service.

Specifications 3 to 7 include two variables that reflect how operators adjust the prices in the plans that bundle the broadband and the voice services. The variable *LimitedVoice* is negative and significant in all specifications, showing that plans that offer a limited number of telephone calls are cheaper than those that offer unlimited calls. On the other hand, the coefficient of the variable *MinutesVoice* is positive and almost zero (due to the unit 'minutes') and not significant. Hence, the inclusion of additional minutes of voice in the plan does not have a strong effect in the prices, but it has a positive effect as expected.

The other aspect of interest in our analysis is to determine how the inclusion of a smartphone in the plan changes the tariff design. The information available in our data set does not allow identifying which is the part of the monthly bill that is dedicated to finance the price of the smartphone. In spite of this, we can observe that the brand of the handset have an impact on the monthly tariff. The variable *Smartphone* uses as reference the SIM-only plans and shows that the plans that include an iPhone or a Samsung might be over 35% more expensive than SIM-only plans. Also, the coefficients of these dummies show that plans with iPhone are more expensive than plans with Samsung devices. Interestingly, the dummy representing the rest of brands, *Other Brands*, is positive but not significant. Operators may set higher prices for the plans with an iPhone or a Samsung because this choice denotes a higher willingness to pay. The extra-charge may also reflect the higher production

[72] For the dummy variables we follow the interpretation of Halvrosen and Palmquist, 1980 in semi-logarithm models coefficients are interpreted in the following way 100*[exponential (coefficient)-1] with respect to the reference.

costs of these brands (iPhone and Samsung are leaders in launching newest technologies), or either because operators have a small bargaining power in front of manufacturers or because they sign exclusive contracts with these manufacturer.[73] By contrast, the purchase of a smartphone with another brand does not imply an extra charge in the price.[74]

Another question that is relevant for our analysis is to determine how operators use the discounts in the price of smartphones to attract consumers. Unfortunately, our data set has many less observations (N=630) that contain information about the discounts granted by operators for the smartphone. In spite of this, we have repeated the estimations of Table 6 to analyse the effect of the *Discount*. Results show that discounts have a positive and significant effect on prices, which implies that operators cross-subsidize the handsets with the price of the broadband plan to attract consumers (see Table 2A in the Appendix).

Finally, we consider another group of variables that are related to the operator's commercial policy. The variable *Contract Duration* shows a positive relation with the price but is not significant in any of the specifications considered. The duration of the contract should have a negative impact on the price, but as we have explained before the duration of the contract is correlated with the acquisition of a smartphone, which has the effect of increasing the monthly price. On the other hand, the variables *HistoricOperator* and *Nplans* are not significant in any specification. This suggests that historical operators do not have a different pricing strategy or a first-mover advantage with respect to the other MNOs. Moreover, we cannot conclude that operators use the number of plans to screen consumers or to moderate competition.

[73] Sinkinson (2014) analyses exclusive contract that AT&T signed with iPhone in the US between 2007 and 2011. Lyons (2013) reports that according to some reports, after the adoption of this agreement the average iPhone user consumed ten times more bandwidth than a typical smartphone user. This could have motivated the introduction of three-part tariffs by AT&T.

[74] A number of manufacturers now offer budget versions of smartphones, usually with reduced functionality, a smaller internal memory or less popular operating system (eg: Windows phone).

Table 6: Estimation Results: Mobile Broadband and Voice on Smartphone: All plans.

Dependent variable	**Specification 1**	**Specification 2**	**Specification 3**	**Specification 4**	**Specification 5**	**Specification 6**	**Specification 7**
Log Price (*price*)	**OLS**	**OLS**	**OLS**	**OLS**	**2SLS**	**2SLS**	**2SLS**
Independent variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Penetration	**0.002***	**0.001**	**0.005**	**0.004**	**-0.014**	**-0.013**	**-0.012**
	(0.001)	(0.001)	(0.004)	(0.004)	(0.028)	(0.022)	(0.024)
Download Speed		**0.002*****	**0.002***	**0.002****		**0.002****	
		(0.001)	(0.001)	(0.001)		(0.001)	
Technology (reference: 3G)							
3.5G/3.75G	**-0.08**	**-0.131**	**-0.021**	**-0.143**	**0.122**	**-0.124**	**-0.088**
	(0.123)	(0.132)	(0.221)	(0.185)	(0.232)	(0.186)	(0.193)
4G	**0.164*****	**0.083***	**0.045**	**0.119**	**0.103**	**0.098**	**0.120****
	(0.034)	(0.045)	(0.088)	(0.09)	(0.065)	(0.085)	(0.058)
Volume	**0.103*****	**0.096*****	**0.091*****	**0.095*****	**0.096*****	**0.096*****	**0.097*****
	(0.007)	(0.007)	(0.015)	(0.013)	(0.014)	(0.012)	(0.011)
Volume²	**-0.002*****	**-0.001*****	**-0.001*****	**-0.001*****	**-0.001*****	**-0.001*****	**-0.001*****
	(0.0003)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0002)
Limited Data	**-0.545*****	**-0.526*****	**-0.440*****		**-0.439*****		
	(0.05)	(0.066)	(0.141)		(0.101)		
Penalty (reference: Unlimited data)							
Speed reduction				**-0.489*****		**-0.481*****	**-0.439*****
				(0.142)		(0.139)	(0.116)
Jump to pay as you go				**-0.574*****		**-0.525*****	**-0.490*****
				(0.172)		(0.186)	(0.125)
Jump to new allowance				**-0.454*****		**-0.454*****	**-0.437*****
				(0.141)		(0.145)	(0.113)
End of service				**-0.734*****		**-0.776*****	**-0.673*****
				(0.155)		(0.148)	(0.121)
Limited Voice Minutes			**-0.461*****	**-0.449*****	**-0.441*****	**-0.448*****	**-0.406*****
			(0.093)	(0.095)	(0.083)	(0.095)	(0.083)
Minutes of Voice			**0.00900**	**0.01100**	**0.00500**	**0.00400**	**0.00500**
			(0.007)	(0.008)	(0.012)	(0.011)	(0.011)
Smartphone (reference: SIM only)							
iPhone			**0.306****	**0.360****	**0.244*****	**0.373*****	**0.248****
			(0.129)	(0.146)	(0.082)	(0.136)	(0.097)
Samsung			**0.233**	**0.325***	**0.225****	**0.347****	**0.266*****
			(0.14)	(0.16)	(0.091)	(0.151)	(0.101)
Other brands			**0.063**	**0.125**	**0.102**	**0.126**	**0.079**
			(0.15)	(0.177)	(0.12)	(0.16)	(0.122)
Contract Duration			**0.004**		**0.003**		
			(0.003)		(0.003)		
Historic Operator			**0.06**	**0.099**	**0.047**	**0.09**	**0.096**
			(0.08)	(0.098)	(0.07)	(0.092)	(0.086)
Nplans			**-0.001**	**-0.002**	**0.001**	**-0.001**	**-0.001**
			(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Time Dummy (reference: year 2011)							
year 2012	**-0.070***	**0.046**	**-0.093**	**-0.038**	**0.119**	**0.262**	**0.144**
	(0.042)	(0.049)	(0.115)	(0.123)	(0.508)	(0.418)	(0.423)
year 2013	**-0.143****	**-0.027**	**-0.168**	**-0.319****	**0.282**	**0.256**	**0.161**
	(0.062)	(0.074)	(0.126)	(0.154)	(0.897)	(0.785)	(0.789)
year 2014	**-0.311*****	**-0.12**	**-0.406*****	**-0.468****	**0.022**	**0.180**	**0.110**
	(0.063)	(0.073)	(0.146)	(0.221)	(0.976)	(0.832)	(0.885)
Constant	**3.866*****	**3.935*****	**3.970*****	**3.902*****	**4.645*****	**4.574*****	**4.615*****
	(0.092)	(0.104)	(0.164)	(0.212)	(1.254)	(0.906)	(1.031)
R^2	*0.46*	*0.42*	*0.49*	*0.54*	*0.50*	*0.51*	*0.54*
Number of observations (N)	*2726*	*1998*	*1605*	*1397*	*2091*	*1397*	*1803*
p-value Hansen J-test				0.1930	0.1930	0.1930	0.1930
p-value F-test (Ho: weak instruments)				0.0000	0.0000	0.0000	0.0000

All specifications include country dummies which are not reported for brevity. Standard errors are robust to heteroskedasticity and are clustered by country. Standard errors are in parenthesis. The estimated coefficients are in bold. Significance at * 10%, ** 5%, *** 1% level.

6. Effects of competition on prices

This section introduces a new group of variables in the pricing model to examine how operators adjust the tariffs to the regulation and the intensity of competition. The FCC data set does not include information about the characteristics of national markets and their regulation. In order to address this limitation, we re-estimate the model for a sub-sample of 20 European countries for which we have additional information from DG-CONNECT.[75]

DG-CONNECT provides information about the market shares in terms of subscribers of the leading and the second operator in EU countries. This has

[75] Due to the lack of information, we have excluded from the analysis Iceland, Norway and Switzerland.

allowed us to construct the variable *HHI Operator*, which is a Hirschman Herfindahl Index constructed as the sum of the squares of the market shares of the leading, the second and the rest of operators in each country.[76] We expect that markets with a high concentration exhibit higher prices. In spite of this, market concentration can also be related with the efficiency of leading operators, which can benefit of scale and scope economies, and this should have a negative effect on prices. The inclusion of country fixed effects should mitigate the endogeneity problem associated with *HHI Operators* as the fixed effects can capture unobserved "operators' efficiencies" in each country. Table 7 shows that all countries in our sub-sample have a concentration level between 33.5 and 38, with the exception of Luxemburg, which has a higher concentrated market.

The FCC dataset does not include information about the plans of MVNOs. But we can study if the presence of this type of operators affects competition and the prices of MNOs. For this objective, we use the variable *MVNO*, which is defined as the number of this type of operators in the country.

Table 7: Competition and Regulation Indicators EU-20, year 2013

	HHI Operator	MVNOs	MTR ($PPP)
Austria	34.0	16	2.43
Belgium	34.2	2	1.42
Czech Republic	35.0	58	0.12
Denmark	35.5	2	0.12
Estonia	34.1	1	2.79
Finland	34.2	17	3.10
France	33.7	37	1.01
Germany	33.7	3	2.46
Hungary	36.1	4	0.02
Ireland	33.9	5	3.14
Italy	33.5	16	2.02
Lithuania	34.8	9	1.18
Luxembourg	41.1	2	9.47
Poland	34.1	15	1.06
Portugal	37.7	4	2.11
Slovenia	37.9	3	5.38
Spain	34.0	21	4.68
Sweden	33.9	34	0.21
The Netherlands	37.4	52	2.90
United Kingdom	34.5	13	2.64

[76] The *HHI Operators* is calculated first as the sum of squares of the proportion of subscribers for the incumbent, the second largest operator, and the rest of operators. This summation is then multiplied by one hundred; hence the *HHI Operator* can take values above cero and below one hundred.

Table 7 shows that the number of MVNOs differs importantly across countries and it is especially high in Czech Republic, The Netherlands, France and Sweden. It is expected that the number of MVNOs will have a negative impact on the broadband prices since these operators usually adopt aggressive commercial policies to attract low income/light volume consumers. In spite of this, many MVNOs have entered in niche markets and in some cases they are low-cost subsidiaries of MNOs. Another important aspect to be considered is that in many countries MVNOs have still not reached any agreement with MNOs in order to provide 4G services.

Finally, the variable *MTR* represents the regulated mobile termination rates ($PPP) set by NRAs in each EU country. The termination rates are the prices that mobile operators charge for terminating the telephone calls of their rivals in their own network.[77] These rates do not directly affect the cost of the broadband service but they do affect the cost of plans that include minute allowances. Termination rates increase the costs of off-net calls and should affect more those operators with a larger proportion of outgoing calls. In the last year, the European authorities have recommended NRAs to implement a "glide-path" to gradually reduce termination fees towards the interconnection costs and to eliminate rates asymmetries between operators.[78] This policy has favored the convergence in prices of on-net and off-net calls and might have favored the change from usage based prices to non-linear prices. Table 7 shows the level of MTRs in 2013 in the group of EU countries analysed.

Table 8 shows the estimation results when we add the new variables in the pricing equation. In most specifications, results for the variables *Speed*, *Volume*, *Limited Data, Limited Voice Minutes* and *Smartphone* are similar to those of Table 6. This suggests that the pricing structure of the European operators is similar to the one we have found in the previous analysis. In the case of the variable *Penalty*, we obtain negative coefficients as before, although now the coefficients of specification 4 and 6 are not significant.

Focusing now on the variables reflecting the level of competition and regulation in the market we observe that *HHI Operator* and *MTR* are not significant in any specification. This would suggest that market concentration

[77] Armstrong (2002), Vogelsang (2003), and Calzada and Trillas (2005) review the literature on interconnection prices.
[78] See for example Kaugant and Bohlin (2014) and Genakos and Valletti (2014).

and the regulation of termination charges do not affect the design of mobile broadband plans. In the first case, the result could be a consequence of the way in which we have constructed the variable *HHI Operator*, since we have grouped the market shares of all operators that are not the leader and its main competitor in the market. Therefore, this variable does not reflect well the presence of small operators that use alternative commercialization strategies and target specific groups of consumers. In the case of *MTR*, the absence of a clear relationship between the regulation and the retail prices reflect a change in the way operators establish their tariffs. Although termination charges affect the operators' costs of telephone calls, this does not seem to have a clear effect on the pricing structure.

Table 8: Estimation Results: Mobile Broadband and Voice on Smartphone: Plans EU-20.

Dependent variable	**Specification 1**	**Specification 2**	**Specification 3**	**Specification 4**	**Specification 5**	**Specification 6**	**Specification 7**
Log Price (*price*)	**OLS**	**OLS**	**OLS**	**OLS**	**2SLS**	**2SLS**	**2SLS**
Independent variables	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Penetration	**0.004**	**0.002**	**0.015**	**0.010**	**-0.014**	**-0.016**	**-0.021**
	(0.006)	(0.007)	(0.013)	(0.014)	(0.022)	(0.023)	(0.019)
Download Speed		**0.003***	**0.003*****	**0.004*****	**0.004*****	**0.004*****	
		(0.002)	(0.001)	(0.001)		(0.001)	
Technology (reference: 3G)							
3.5G/3.75G	**-0.087**	**-0.148**	**-0.153**	**-0.198**	**-0.161**	**-0.206**	**-0.105**
	(0.191)	(0.194)	(0.219)	(0.209)	(0.205)	(0.195)	(0.197)
4G	**0.199*****	**0.007**	**-0.03**	**-0.011**	**0.001**	**0.021**	**0.131**
	(0.065)	(0.087)	(0.122)	(0.102)	(0.122)	(0.104)	(0.085)
Volume	**0.119*****	**0.100*****	**0.090*****	**0.081*****	**0.090*****	**0.081*****	**0.091*****
	(0.015)	(0.015)	(0.015)	(0.017)	(0.014)	(0.016)	(0.014)
Volume²	**-0.002*****	**-0.002*****	**-0.002*****	**-0.001*****	**-0.002*****	**-0.001*****	**-0.001*****
	(0.0002)	(0.0002)	(0.0002)	(0.0004)	(0.0002)	(0.0002)	(0.0002)
Limited Data	**-0.441*****	**-0.423*****	**-0.326***		**-0.324****		
	(0.124)	(0.141)	(0.159)		(0.13)		
Penalty (reference: Unlimited data)							
Speed reduction				**-0.329***		**-0.343****	**-0.454*****
				(0.181)		(0.157)	(0.152)
Jump to pay as you go				**-0.407**		**-0.414***	**-0.463*****
				(0.245)		(0.226)	(0.16)
Jump to new allowance				**-0.301***		**-0.300****	**-0.298****
				(0.167)		(0.14)	(0.122)
End of service				**-0.014***	**-0.015***	**-0.013**	**-0.012**
				(0.202)		(0.183)	(0.14)
Limited Voice Minutes			**-0.629*****	**-0.633*****	**-0.613*****	**-0.616*****	**-0.578*****
			(0.074)	(0.081)	(0.067)	(0.074)	(0.071)
Minutes of Voice			**0.027*****	**0.027*****	**0.025*****	**0.027*****	**0.024*****
			(0.009)	(0.009)	(0.008)	(0.008)	(0.007)
Smartphone (reference: SIM only)							
iPhone			**0.371****	**0.358****	**0.345****	**0.344****	**0.238****
			(0.143)	(0.145)	(0.134)	(0.143)	(0.094)
Samsung			**0.312****	**0.335*****	**0.268****	**0.303****	**0.211*****
			(0.121)	(0.114)	(0.123)	(0.127)	(0.067)
Other brands				**0.183**		**0.163**	**0.166**
			(0.201)	(0.231)	(0.19)	(0.223)	(0.134)
Historic Operator			**0.064**	**0.114**	**0.041**	**0.094**	**0.069**
			(0.1)	(0.127)	(0.101)	(0.124)	(0.133)
Nplans			**0.007**	**0.008**	**0.006**	**0.008**	**0.005**
			(0.008)	(0.015)	(0.007)	(0.013)	(0.007)
HHI Operator			**0.135**	**0.251**	**0.273**	**0.303**	**0.003**
			(0.152)	(0.162)	(0.184)	(0.179)	(0.117)
MVNO			**-0.017***	**-0.014***	**-0.015***	**-0.013**	**-0.012**
			(0.017)	(0.016)	(0.024)	(0.022)	(0.015)
MTR			**-0.001**	**0.008**	**-0.052**	**-0.037**	**-0.049**
			(0.032)	(0.033)	(0.044)	(0.051)	(0.041)
Time Dummy (reference: year 2011)							
year 2012	**0.003**	**0.105**	**-0.610*****	**-0.458*****	**-0.328**	**-0.194**	**-0.252**
	(0.125)	(0.136)	(0.092)	(0.143)	(0.226)	(0.261)	(0.225)
year 2013	**-0.153**	**-0.111**	**-0.864*****	**-0.744*****	**-0.253**	**-0.203**	**-0.281**
	(0.155)	(0.188)	(0.258)	(0.253)	(0.472)	(0.429)	(0.356)
year 2014	**-0.470***	**-0.202**	**-1.206*****	**-0.949****	**-0.358**	**-0.188**	**-0.173**
	(0.267)	(0.312)	(0.344)	(0.363)	(0.641)	(0.655)	(0.581)
Constant	**3.382*****	**3.472*****	**1.128**	**2.096**	**0.361**	**1.463**	**3.499***
	(0.28)	(0.304)	(1.758)	(2.341)	(1.759)	(2.452)	(2.003)
R^2	*0.45*	*0.35*	*0.48*	*0.50*	*0.47*	*0.49*	*0.57*
Number of observations (N)	*1415*	*1041*	*822*	*643*	*822*	*643*	*862*
p-value Hansen J-test				0.3487	0.3487	0.3487	0.3487
p-value F-test (Ho: weak instruments)				0.0000	0.0000	0.0000	0.0000

All specifications include country dummies which are not reported for brevity. Standard errors are robust to heteroskedasticity and are clustered by country. Standard errors are in parenthesis. The estimated coefficients are in bold. Significance at * 10%, ** 5%, *** 1% level.

Finally, the variable *MVNO* is negative and significant in specifications 3 to 5. The interpretation of the coefficient is that the entry of an additional MVNO into the market might produce a decrease in the price of up to 1.5%. Although MVNOs have to pay compensation to MNOs in order to use their networks, they contribute substantially to increase competition and to reduce prices.

7. Conclusions

This paper has used a rich dataset of smartphone broadband plans in 37 countries to study the pricing structure of mobile operators in the period 2011-2014. The main contribution of the paper is to explain how operators design their multi-tier tariffs to segment consumers and to adapt to competition. The plans are characterised by data and voice minutes allowances that allow operators to segment customers according to their needs (second degree price discrimination) and to reduce congestion. Most mobile plans limit Internet usage to a few gigabytes per month. As a result, consumers can contract the plan than better suits their needs. In addition to this, some operators offer unlimited data plans at a significantly higher price. Metered plans include different types of penalties that are applied to the consumers that exceed the contracted volume allowances. These penalties can consist in a drastic reduction of the data transmission speeds ('bandwidth throttling') or in monetary penalties such as moving consumers to a plan with a higher allowance or setting 'overage charges'. We have identified the impact that these data caps have on the monthly tariff regarding unlimited usage plans. In addition to this, overage charges imply an additional payment to the consumers that exceed the cap, which can result in an unexpected high bill if consumers are unaware of the conditions of their contracts.

Another dimension that differentiates mobile plans is the download speed of the Internet service. But in contrast to the situation for fixed communications, the most relevant feature of mobile broadband plans is the volume allowance and the download speed has a much smaller effect in the price.[79] It is possible that the technological limitations of the wireless communications makes difficult for operators to differentiate their plans according to the download

[79] The ITU in its report "Measuring the Information Society 2013" analyses mobile broadband prices and mentions that data allowances are the main driver for mobile broadband plans.

speed. The technology used to provide the service also has an impact on broadband prices. After controlling for speed, we have found that during the first stages of the transition from 3G to 4G operators have been able to commercialize 4G plans as a premium service. But when we consider the whole sample of plans in our data set, we only find slight evidence that the provision technology affects prices through other channels than the download speed.

Most plans include voice minutes allowances, which are usually quite high. The pricing structure of the voice service is similar to those of the broadband service. Consumers contract voice minutes allowances, and have to pay a per-minute price if they exceed the cap. Many plans offer unlimited voice at a significantly higher price. Another interesting feature of the tariff is that operators do not longer distinguish between on-net and off-net calls, or between mobile to mobile and mobile to fixed calls. As we have argued, this is possibly a consequence of the regulation of mobile termination charges (MTRs).

The second most important contribution of the paper is to explain how operators modify their prices when they bundle the broadband service together with a smartphone. We have shown that smartphone discounts are partly subsidized with higher prices of the broadband service. Indeed, operators distribute the cost of the handset along the length of the contract, allowing customers to finance the smartphones and tying them for a longer period of time. We have also shown that the price of the broadband service varies depending on the smartphone brand bundled in the plan. While the plans that include iPhone and Samsung smartphones are more expensive than SIM-only plans, the plans that bundle other brands do not show a significant difference in the price with respect to SIM-only plans. This result suggests that operators might use the information revealed by consumers about their willingness to pay for some brands to set higher prices (third degree price discrimination). Although this situation might also reflect the higher price that operators have to pay for some handsets to the manufacturer, due for example to the existence of exclusivity agreements.

The last part of the paper conducts a separate analysis of the pricing policies of mobile operators in a group of 20 EU countries. For these countries we can consider additional variables reflecting the market structure and the regulation of the country. Our analysis shows that the operators in these countries use a similar multi-tier pricing system than the one found for the whole sample. But we have not found a relation between market concentration and broadband prices. Moreover, the regulation of MTRs does not appear to drive the level of broadband tariffs. This can reflect the application of the "glide path" mechanism in the EU and the small impact of off-net calls on the costs of mobile operators. On the other hand, we have found that the intensity in the entry of MVNOs does have a pro-competitive effect and pushes down MNOs' prices.

One recent aspect that affects the pricing of communications services and that has not been considered in this work is the bundling of fixed and mobile voice and data services, and sometimes also of pay-per-view TV.[80] This type of plans is becoming very popular because it facilitates the control of the expenditure on communication services and offer important discounts. In some countries the popularization of these plans has forced the restructuring of the telecommunications market toward "platform-converged market players" that are able to provide all core communications services. In the years to come it would be interesting to study the effects of these changes in competition and in the operators' pricing strategy.

[80] Grzybowski and Liang (2014) estimate demand for quadruple play mobile tariffs.

8. Appendix

Annex 1: Variables Correlation Matrix

	Price	Penetration	Speed	4G Technology	Volume	Volume	Limited Data	Minutes of Voice	Limited Voice	Contract duration	Historic Operator	Nplans	HHI Operator	MVNO	MTR
Price	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Penetration	-0.1955	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Speed	0.1769	0.1505	1	-	-	-	-	-	-	-	-	-	-	-	-
4G Technology	0.1094	0.2019	0.6429	1	-	-	-	-	-	-	-	-	-	-	-
Volume	0.1677	0.0974	0.1643	0.1511	1	-	-	-	-	-	-	-	-	-	-
Volume^2	0.0389	0.0824	0.0658	0.0951	0.9125	1	-	-	-	-	-	-	-	-	-
Limited Data	-0.0006	-0.0391	0.0874	0.0529	0.1087	0.0456	1	-	-	-	-	-	-	-	-
Minutes of Voice	0.1461	0.0202	-0.1402	-0.1492	-0.0174	-0.0381	-0.0441	1	-	-	-	-	-	-	-
Limited Voice	-0.2848	-0.0535	-0.3788	-0.4226	-0.0778	-0.0037	-0.0884	0.2733	1	-	-	-	-	-	-
Contract duration	0.063	-0.1712	0.0223	0.063	0.0094	0.0132	0.0075	0.1602	0.0984	1	-	-	-	-	-
Historic Operator	0.1154	-0.0689	0.1951	0.181	-0.0412	-0.0543	-0.0142	-0.016	-0.1557	-0.0644	1	-	-	-	-
Nplans	0.104	0.0466	0.3436	0.2521	-0.0177	-0.0484	0.1419	-0.165	-0.3942	-0.2337	0.3403	1	-	-	-
HHI Operator	0.0241	-0.184	-0.0222	0.0176	0.0698	0.0801	0.0529	-0.0433	0.1093	0.0361	0.0071	-0.0424	1	-	-
MVNO	0.0692	0.1202	0.1264	0.0498	-0.1189	-0.0897	0.0807	-0.0613	-0.2194	-0.0016	0.1327	0.4642	0.1471	1	-
MTR	-0.1000	-0.219	-0.4221	-0.4548	0.0075	0.0482	-0.199	0.0953	0.3446	0.0754	-0.2801	-0.3567	0.0811	-0.2651	1

Annex 2: Average discounts ($PPP) on smartphone when bundled with tariff by country.

	Plans	iPhone	Samsung	Rest brands
Australia	0	-	-	-
Austria	0	-	-	-
Belgium	17	335.9	327.2	-
Brazil	0	-	-	-
Bulgaria	0	-	-	-
Canada	32	374.5	253.5	-
Chile	3	726.8	-	-
Czech Republic	10	198.8	177.0	-
Denmark	4	154.0	-	-
Estonia	9	-	149.4	-
Finland	0	-	-	-
France	51	343.0	156.9	-
Germany	36	547.2	459.7	-
Greece	-	-	-	-
Hong Kong	12	589.9	394.2	-
Hungary	20	604.5	681.7	-
Iceland	23	92.3	-	-
India	9	64.0	-	231.5
Ireland	68	440.6	589.1	371.9
Israel	1	-	179.5	-
Italy	6	591.3	-	-
Japan	7	-	479.2	-
Korea	13	107.5	-	-
Lithuania	16	1247.4	389.3	212.6
Luxembourg	2	-	527.6	275.7
Mexico	5	1019.3	891.5	-
New Zealand	22	219.0	136.0	-
Norway	22	388.0	-	-
Poland	5	534.1	754.2	-
Portugal	9	16.4	-	-
Singapore	4	-	572.0	-
Slovakia	7	531.6	201.7	-
Slovenia	19	189.9	-	-
Spain	14	225.0	-	-
Sweden	12	563.4	-	-
Switzerland	41	166.9	305.3	77.5
The Netherlands	36	452.1	290.4	-
Turkey	-	-	-	-
United Kingdom	25	439.5	413.2	385.2
United States	136	451.8	407.8	-
Total	696	358.2	391.1	327.0

Annex 3: Estimation Results: Pass-through of discount on smartphone to the price of the plan.

Dependent variable	**Specification 1**	**Specification 2**	**Specification 3**
Log Price (*price)*	**2SLS**	**2SLS**	**2SLS**
Independent variables	**Coefficient**	**Coefficient**	**Coefficient**
Discount	**0.110*** **	**0.110*** **	**0.121*** **
	(0.023)	(0.023)	(0.026)
Penetration	**-0.022**	**-0.027**	**-0.025**
	(0.019)	(0.024)	(0.024)
Download Speed			
Technology (reference: 3G)			
3.5G/3.75G	-	-	-
4G	**0.044**	**0.007**	**0.06**
	(0.266)	(0.202)	(0.199)
Volume	**0.134*** **	**0.122*** **	**0.123*** **
	(0.011)	(0.014)	(0.013)
Volume²	**-0.003*** **	**-0.002*** **	**-0.002*** **
	(0.0003)	(0.0004)	(0.0003)
Limited Voice Minutes	**-0.531*** **	**-0.483*** **	**-0.452*** **
	(0.127)	(0.106)	(0.108)
Minutes of Voice	**0.026* **	**0.011**	**0.012**
	(0.015)	(0.009)	(0.009)
Smartphone (reference: SIM only)			
iPhone			**0.105**
			(0.166)
Samsung			**0.026**
			(0.173)
Other brands			-
Contract Duration	**-0.007**		**-0.011**
	(0.005)		(0.008)
Historic Operator	**0.074**	**0.125**	**0.132* **
	(0.075)	(0.081)	(0.079)
Nplans	**0.003**	**0.004**	**0.004**
	(0.003)	(0.003)	(0.003)
Constant	**5.641*** **	**5.556*** **	**5.437*** **
	(1.811)	(2.157)	(2.07)
R^2	*0.68*	*0.65*	*0.65*
Number of observations (N)	*507*	*630*	*630*
p-value Hansen J-test	0.1930	0.1930	0.1930
p-value F-test (Ho: weak instruments)	0.0000	0.0000	0.0000

All specifications include country and time dummies which are not reported for brevity. Standard errors are robust to heteroskedasticity and are clustered by country. Standard errors are in parenthesis. The estimated coefficients are in bold. Significance at * 10%, ** 5%, *** 1% level.

References

Armstrong, M., 2002. "The theory of access pricing and interconnection", *Handbook of Telecommunications Economics*, Vol. I, Elsevier: Amsterdam, 297-384.

Bacache, M., Bourreaum M., and Gaudin, G., 2014. "Dynamic Entry and Investment in New Infrastructures: Empirical Evidence from the Fixed Broadband Industry", *Review of Industrial Organisations, forthcoming*, 44 (1), 179-209.

Bouckaert, J., Van Dijk, T., and Verboven, F., 2010. "Access regulation, competition, and broadband penetration: An international study", *Telecommunications Policy*, 34, 661-671.

Briglauer, W., Ecker. G., and Gugler, K., 2013. "The impact of infrastructure and service-based competition on the development of next generation access networks: recent evidence from the European member states", *Information Economics and Policy*, 25, 142-153.

Calzada, J. and Martínez-Santos, F., 2014a. "Broadband prices in the European Union: Competition and commercial strategies", *Information Economics and Policy*, 7, 24–38.

Calzada, J. and Martínez-Santos, F., 2014b. "Competencia en el Mercado de banda ancha móvil en España", *Cuadernos Económicos del ICE*, 88, 97-129.

Calzada, J. and Trillas, F., 2006. "Los precios de precios de interconexión en las telecomunicaciones: de la teoría a la práctica", *Hacienda Pública Española*, Vol. 173, 2, 85-125.

Cambini, C. and Jiang, Y., 2009. "Broadband Investment and Regulation: A literature Review," *Telecommunications Policy*, 33 (10-11), 559-574.

Distaso, W., Lupi, P. and Manenti, G., 2006. "Platform Competition and Broadband Uptake: Theory and Empirical Evidence", *Information Economics and Policy*, 18 (1), 87-106.

Economides, N. and Hermalin, B.E., 2015. "The Strategic Use of Download

Limits by a Monopoly Platform", forthcoming in *Rand Journal of Economics*, 46, 2, 297-327.

European Commission, 2009. "15th Progress Report on the Single European Electronic Communications Market – 2009".

European Commission, 2011. "Broadband Internet Access Costs (BIAC)". Final Report, Information Society and Media Directorate-General.Van Dijk – Management Consulting.

FCC, 2015. "Fourth International Broadband Data Report", Federal Communications Commission, Washington.

Gabaix, X. and Laibson, D., 2006. "Shrouded attributes, consumers myopia, and information suppression in competitive markets", *Quarterly Journal of Economics*, 121 (2), 505-540.

Genakos, C. and Valletti, T., 2014. "Evaluating a decade of mobile termination rate regulation", mimeo.

Grajek, M., and Röller, L.-H., 2012. "Regulation and investment in network industries: Evidence from European telecoms", *Journal of Law and Economics*, 55 (1): 189-216.

Greenstein, S. and McDevitt, R., 2011a. "The Broadband Bonus: Estimating broadband Internet's economic value", *Telecommunications Policy*, 35 (7), 617-632.

Greenstein, S. and McDevitt, R., 2011b."Evidence of a modest price decline in US broadband services", *Information, Economics and Policy*, 23 (2), 200-211.

Gruber, H., and Koutroumpis, P., 2013. "Competition enhancing regulation and diffusion of innovation: the case of broadband networks", *Journal of Regulatory Economics*, 43: 168-195.

Grzybowski, L. and Dauvin, M., 2014. "Estimating broadband diffusion in the EU using NUTS1 regional data", *Telecommunications Policy*, 38(1), 96-104.

Grzybowski, L. and Liang, J., 2014. "Estimating demand for quadruple-pay tariffs: The impact on consumer surplus", mimeo.

Hoernig, S., 2001. "Collusion and confusion?", mimeo.

Kaugant, C. and Bohlin, E., 2014. "Impact of mobile termination rates on retail prices: the implications for regulators", *Info*, Vol. 16 (2), 80-93.

Lee, S., Marcu, M. and Lee, S., 2011. "An Empirical analysis of fixed and mobile broadband diffusion", *Information Economics and Policy*, 23, 227-233.

Leider, S. and Sahin, O., 2015. Contracts, biases and consumption of access services, mimeo.

Leiner, B.M., Cerf, V.G., Clark, D.D., Kahn, R.E., Kleinrock, L., Lynch, D.C., Postel, J., Roberts L.G., Wolff S., 2003. "A Brief History of the Internet", *Internet Society.*

Lyons, D., 2013. "Internet Policy's Next Frontier: Data Caps, Tiered Service Plans, and Usage Broadband Pricing", *Federal Communications Law Journal*, 66, 1, 1-44.

Nardotto, M., Valletti, T. and Verboven, F., 2014. "Unbundling the Incumbent: Evidence from UK broadband," CEIS Research Paper 331, Tor Vergata University, CEIS.

OFCOM, 2014. "Measuring mobile broadband performance in the UK", Research document, November.

Pereira, P. and Ribeiro, T., 2010. "The impact on broadband access to the Internet of the dual ownership of telephone and cable networks", *International Journal of Industrial Organisations,* 29, 283–293.

Sinkinson, M., 2014. "Pricing and Entry Incentives with Exclusive Contracts: Evidence from Smartphones", mimeo.

Srinuan, C., Srinuan, P., and Bohlin, E., 2012. "An analysis of mobile Internet access in Thailand: Implications for bridging the digital divide". *Telematics and Informatics 29(3),* 254-262.

Srinuan, C., Srinuan, P., and Bohlin, E., 2013. "Pricing strategies and innovations in the Thai mobile communications market", *Info*, 15 (1) , 61 – 77.

Srinuan, C., Srinuan, P., and Bohlin, E., 2012. "Fixed and mobile broadband substitution in Sweden". *Telecommunications Policy, 36(3),* 237-251.

Tirole, J., 1988. "The Theory of Industrial Organisations", Cambridge, MA: *The MIT Press.*

Vogelsang, I., 2003. "Price Regulation of access to telecommunications networks", *Journal of Economic Literature*, 41 (3).

Vogelsang, I., 2010. "The Relationship between mobile and fixed-line communications: a survey", *Information Economics and Policy*, 22(1): 4-17.

Wallsten, S. and Riso J.L., 2010a. "Residential and Business Broadband Prices: Part 1: An Empirical Analysis of Metering and Other Price Determinants", Technology Policy Institute.

Wallsten, S. and Riso, J.L., 2010b. "Residential and Business Broadband Prices: Part 2: International comparisons", Technology Policy Institute.

Wallsten, C. and Mallahan, 2010. "Residential broadband competition in the United States", SSRN eLibrary.

Wilson, R., 1993, "Non linear pricing". New York: *Oxford University Press.*

Zhu, T., Liu, H., and Chintagunta, P., 2011. "Wireless Carriers' Exclusive Handset Arrangements: An Empirical Look at the iPhone", Working Papers 11-35, NET Institute.

Chapter 4

Competition in the Spanish mobile broadband market[81]

1. Introduction

Telecommunications and information society services have established themselves as one of the main drivers of economic development and social cohesion. Indeed, empirical evidence shows that broadband access has a positive impact on such macroeconomic factors as GDP, employment and productivity.[82]

In 2010, the European Commission (EC) launched the European Digital Agenda 2020 with the primary objective of creating a European Digital Single Market. The Digital Agenda also established several short- and mid-term goals. The most immediate of these was that all EU citizens should have the possibility of accessing the Internet by 2013. This objective was in fact met months before the end of 2013, with more than 95 and 99 percent fixed and mobile broadband coverage respectively, reaching 100 percent Internet coverage thanks to satellite access for more remote areas. In Spain, fixed broadband reaches over 95 percent of households, and mobile broadband covers 98 percent of the territory.

A further objective established by the Digital Agenda is to ensure that by 2020 the entire EU population has broadband service access with speeds of at least 30 Mbps, and that at least half of all households can surf at speeds exceeding 100 Mbps. For this reason, the EC and National Regulatory Authorities (NRAs) are currently promoting investment in the next generation access networks of fixed fibre networks (FTTx) and fourth generation (4G) mobile technology.

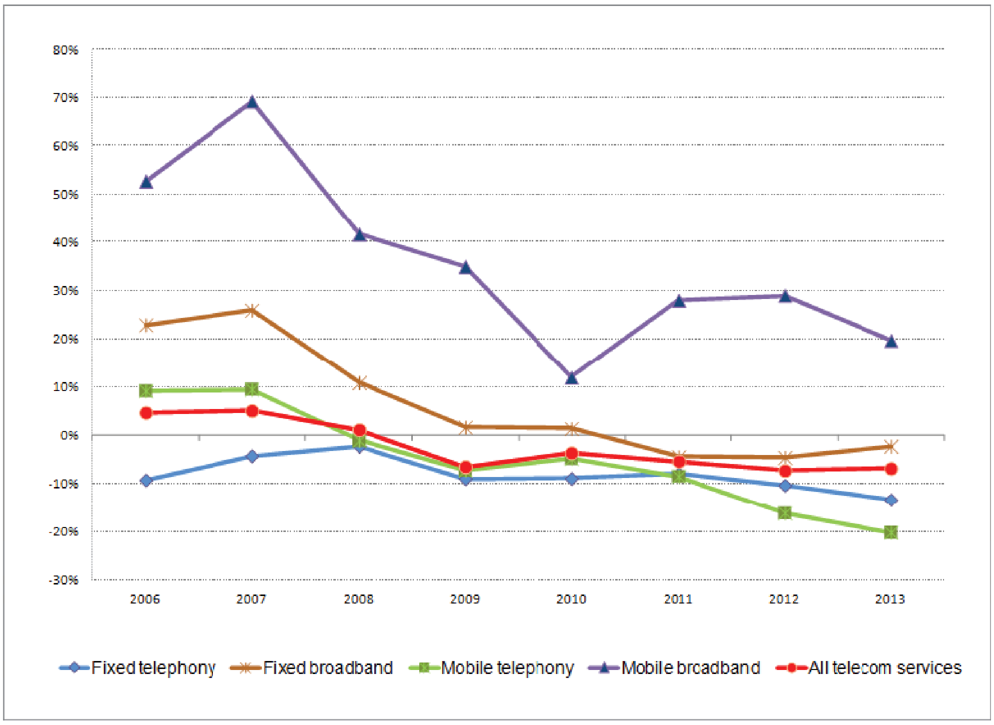
These efforts to promote broadband have been made in a context of deep

[81] This chapter has been previously published as "Calzada, J. and Martínez-Santos, F., 2014. Competencia en el Mercado de banda ancha móvil en España, *Cuadernos Económicos del ICE*, 88, 97-129".

[82] Crandall et al. (2007) find a positive and significant impact of broadband penetration on employment in the United States. Czernich et al. (2011) estimate that a 10% increase in broadband penetration leads to a GDP growth of between 0.9 and 1.5%.

economic crisis and a marked rise in competition, which has significantly cut into telecom operators' revenues. In the EU, these reductions occurred mainly in fixed and mobile voice services, which have traditionally enjoyed a greater weight among operators. At the same time, however, fixed and, especially, mobile broadband have recorded positive growth rates. In Spain, the total revenue generated by the country's telecommunications services has not stopped falling since 2008 (Figure 1). Most notably, there was a significant revenue reduction in mobile and fixed voice traffic in 2013, with reductions of 20.1 and 13.3 percent, respectively. In contrast, the revenue of fixed broadband fell by just 2.2 percent, while mobile broadband revenue rose by 19.7 percent in 2013.

Figure 1: Evolution of annual revenues changes (percentage) in the Spanish Telecoms market



Source: CNMC, annual reports

The healthy financial results posted by mobile broadband services reflect the major expansion of this service in Spain. Thus, between January 2013 and January 2014 penetration increased from 58 to 73 percent, leaving Spain ranked eighth among the EU-28 in terms of take-up levels. In contrast, access to fixed broadband was just 26 percent in 2014, which left Spain ranked tenth from bottom among the EU-28 country in terms of penetration and below the 30 percent European average.

Mobile broadband services facilitate the use of calling and messaging applications that are transforming users' previous communication habits, with a particular impact on fixed and mobile voice services. However, the diffusion of fixed-mobile bundles that include voice services and fixed and mobile broadband means that consumers are not so greatly conditioned by the prices of separate communication services and are making more frequent use of mobile devices to access the Internet.[83]

Interestingly, in Spain the rapid diffusion of mobile broadband has occurred in spite of relatively low Internet usage. According to Eurostat[84], at the beginning of 2013 the proportion of people aged 16 to 74 who accessed the Internet at least once a month was 66 percent in Spain, a significantly lower percentage than that reported in other European countries including France (78 percent), Germany (80 percent) and the United Kingdom (87 percent). Furthermore, 24 percent of the Spanish population was reported as never having used the Internet. Similarly, in Spain only 32 percent of the population reported having bought products or services online in the previous 12 months – a figure that fell well short of the corresponding percentages in France (59 percent), Germany (68 percent) and the UK (77 percent). Given these results, it is interesting to analyse the causes of the low rate of Internet use in Spain compared to that of other EU countries and to determine whether the diffusion of mobile broadband might change this situation.

The rest of this paper is organised as follows. Section 2 describes the technological changes that have facilitated the emergence of new mobile broadband standards and charts the adoption of 4G technology in Spain. Section 3 examines the evolution of mobile broadband penetration in Spain and compares the process with that of other EU countries. It also analyses changes in market structure. Finally, section 4 explains the emergence of new

[83] Several studies have analysed the determinants of substitution of fixed for mobile telephony, leading to ambiguous conclusions. For a review see Vogelsang (2010) and Grzybowski (2012).

[84] See *Eurostat, Community Survey on ICT Usage in Households and by Individuals* (2013). The EC (2013) reports that among the EU-27 countries, 27 percent of people often use their smartphones to access the Internet while 36 percent do so via laptops or tablets. According to this study, age, a lack of skills and price are the main reasons for not using mobile broadband.

business practices in the market, specifically fixed-mobile bundles, and examines in detail Spanish operators' commercial plans in 2014.[85]

2. The technological development of mobile broadband

Technological progress and competition have clearly been two essential factors in the diffusion of mobile voice telephony and, today, they continue to be the key drivers of mobile broadband penetration. In this section, the process of technological innovation that has facilitated the development of mobile broadband services is analysed and the difficulties Spain has encountered in deploying 4G services are examined.

2.1. The birth of mobile broadband

Mobile data services have developed progressively through a series of technological standards. The first generation (1G) commercial mobile network was launched in Japan in 1979[86] using analog technology. The service quickly spread around the globe supported by seven incompatible standards. In the US, a single standard, the Analogue Mobile Phone System, was implemented. This service was rapidly diffused by reducing equipment costs and by facilitating national roaming. In Europe, by contrast, the existence of a number of incompatible national systems led to market fragmentation. This, combined with a costly service and handsets (which could only be used at that time for voice service), meant the number of users never rose above a few million.

The market situation underwent a radical change with the introduction of second generation technology (2G) in the second half of the nineties. In 1982, the European Conference of Postal and Telecommunications Administrations recognized the need to develop a European mobile telephone system that

[85] Very few articles have studied the prices of mobile telephony. Grzybowski (2005 and 2008) and Sung and Kwon (2011) show the effect of regulation, costs and market concentration on prices. Calzada and Martínez Santos (2014) analyse the prices of fixed broadband in the EU.

[86] According to Gruber and Valletti (2003), mobile telephony was developed in 1973 by Martin Cooper in Motorola and started to be commercialized by NTT DoCoMO in Tokyo in 1979.

would prevent the 900 Mhz band from being occupied by incompatible national systems. But instead of harmonizing national systems, the decision was taken to create a new technology. Thus, the *Groupe Spécial Mobile*, formed by European operators, designed its own digital mobile telephone system (Hillebrand, 2013). In 1987, the parties involved in the standard defined the basic technical specifications that would characterise 2G technology. The standard thus adopted received the name of Global System for Mobile Communications (GSM) and to formalize the agreement operators in 14 countries, including Spain's Telefónica, signed the GSM Memorandum of Understanding. The signatories undertook to adopt the GSM in their respective countries in 1991, and to ensure the interoperability of infrastructures. In 1989, the GSM was transferred to the European Telecommunications Standards Institute (ETSI) and the standard became mandatory within Europe.

The GSM was launched in Finland in 1991 and quickly spread worldwide. In Spain, GSM-900 licenses were issued to Movistar (Telefónica) and Airtel (later Vodafone) in 1995, and later, in 1998, GSM-1800 licenses were granted to Movistar, Airtel and Amena (later Orange) (Calzada and Estruch, 2011).

Meanwhile, in the USA, Australia, China and India, the choice of standard was left to the individual operators. In the USA, a version of GSM was introduced, but soon other incompatible standards were adopted, hindering national roaming (Gandal et al., 2003). Globally, four 2G standards were deployed, although almost 80 percent of the world population ended up using the GSM while more than 15 percent used the US standard IS-95 (Interim Standard 95)[87]. The literature stresses that market fragmentation in different standards and the obligation to pay to receive calls ("receiving party pays") were factors that delayed the expansion of mobile telephony in America (Gruber and Verboven, 2001; Koski and Kretschmer, 2004).

The chief advantages of 2G were that these networks had lower deployment costs and could withstand a more intensive use of the service. This facilitated the issuing of multiple licenses in each country and helped to foster

[87] The GSM and IS-95 were differentiated by their access systems. The GSM used Time Division Multiple Access (TDMA), which divided the frequency in slots and allocated one to each user. In contrast, the IS-95 used Code Division Multiple Access (CDMA) technology that enabled all users to share the frequency channel, but the signals had a code to distinguish each of the users.

competition[88]. However, 2G had little capacity for data transmission, and could only offer such services as the sending of text messages and voicemail.

In the years that followed, many working groups contributed to improving the standard. The General Packet Radio Service (GPRS) was an evolution of the GSM which allowed packets of information to be sent by performing a simple upgrade of the existing networks. This 2.5G system used Internet Protocol (IP) technology to access Internet content providers. Moreover, consumers could remain connected to the Internet and make calls at the same time. Other 2.5G technologies included Enhanced Data Rates for Global Evolution (EDGE) and CDMA2000. These technologies provided speeds between 40 kbps and 384 kbps, but were still insufficient to support mobile broadband.

In the mid-nineties, the aim of boosting high speed data transmission led the International Telecommunications Union (ITU) to propose a global standard for third generation technology (3G) with higher requirements. It opted for the IMT-2000 (International Mobile Telecommunications 2000), which was based on the CDMA2000 standard developed by Qualcomm. Some of the most salient features of the IMT-2000 were its capacity to enable global roaming through a single terminal and its ability to increase more than 40-fold the transmission speed rates of 2G services.

In Europe, the IMT-2000 gave rise to fears that the GSM would be unable to evolve to meet these new requirements. Thus, the Universal Mobile Telecommunications System (UMTS) Forum sought an alternative for the European 3G. Based on the UMTS Task Force's recommendations, technical specifications for a new standard were established in 1997. A key aspect in this process was that several manufacturers belonging to the ETSI proposed a variation of CDMA2000. This became known as Wideband Code Division Multiple Access (WCDMA) and was incompatible with the North American system,[89] which meant that the handsets and cards that worked with different standards were not compatible.

---

[88] In 1996, the EC approved Directive 96/2/EC, which liberalized the market and established the first of January 1998 as the deadline for issuing the new GSM-1800 licenses (Bekkers, 2001).

[89] According to Cabral and Salant (2013), the US obliged the EU to revoke the ETSI decision requiring the NRAs to use the GSM, on the grounds that this violated the competition policy treaties between the US and the EU. Nonetheless, the European regulatory bodies undertook a reallocation of the spectrum so as to avoid the deployment of CDMA2000.

ETSI's support for WCDMA made it quite clear that it would not be possible to create a single standard for IMT-2000. The EU, US and Japan wanted 3G to give continuity to their 2G standards. At this point it should perhaps be stressed that while the ITU is responsible for establishing the characteristics of international standards, various consortia – comprising different companies and institutions – eventually define the rules that the operators must adhere to in order to comply with the standards. In 1997, taking into account existing interests, ITU finally approved five systems for the IMT-2000 family standards. In the EU, all countries finally adopted the WCDMA, also known as UMTS.

In 1998, participants in the GSM and IS-95 standards created two global projects with the aim of developing 3G standards based on the IMT-2000 requirements. The Third Generation Partnership Project (3GPP) was the association responsible for developing UMTS, and is in charge of maintaining the GSM, EDGE, WCDMA and High Speed Packet Access (HSPA) standards, as well as for developing the new Long Term Evolution (LTE) standard. At the same time, the Third Generation Partnership Project 2 (3GPP2) was the association responsible for developing the CDMA2000, the successor to IS-95. Based on the specifications recommended by the ITU, UMTS and CDMA2000 evolved in parallel.

The UMTS offered a similar voice quality to that offered by fixed telephony and allowed consumers to use multimedia applications and other services that required higher bandwidth, such as teleconferencing or streaming. Additionally, it allowed operators to launch exclusive 3G offers for Internet access via tablets and laptops.

The 3G standard that has enjoyed most success is the UMTS, used by more than 70 percent of subscribers worldwide. However, the diffusion of the UMTS suffered significant delays at the outset (Gruber, 2007). When the licenses were first awarded, neither handsets with 3G capabilities nor many technical specifications for installing the new networks were yet available. It might have been the case that the advances in 3G already made in Japan and the US led the EU to launch its standard when its technology was not yet fully developed. Additionally, the issuing of UMTS licenses coincided with the "dotcom crash" of 2001, at a time when the expectations that the financial markets had placed on telecommunications, especially on the Internet, had been scuppered. This situation, combined with the large amounts of money that operators paid for their licenses at auction, impeded investment in new infrastructure. All in all, carriers preferred to update their current networks rather than to invest in new ones.[90]

On 13 May 2000, the Spanish Government issued four UMTS licenses, becoming the second European country to do so after Finland. A license was granted to each of the existing GSM operators and a fourth license was issued to Xfera (later Yoigo). However, delays in the launch of this technology meant that the Spanish Telecom Regulatory Authority (*Comisión del Mercado de las Telecomunicaciones,* CMT) was forced to recommend the temporary use of the GPRS system. Its objective in doing so was to create demand for new mobile applications. Thus, the first dual UMTS/GPRS SIM cards were put on sale by Vodafone in February 2004 (switching between the two systems according to available coverage), but initially they could only be used on computers as it would take several months for the UMTS handsets to become available.

The new 3G handsets offered a greater number of services, types of application and content display; however, the new features also required more data traffic. To meet the new demand, 3GPP made constant improvements to the UMTS through updates that included 3.5G, 3.75G, and 3.9G. Above all, standards such as HSPA+ were introduced, which could compete in terms of performance with 4G standards such as LTE-Advanced. However, the high 3G latency (response time) and demand for higher transmission speeds, especially after the popularization of smartphones and tablets, meant a new standard had to be introduced.

The transition from 3G to 4G was launched in 2008 when ITU presented a set of requirements known as IMT-Advanced for the implementation of mobile broadband.[91] In the EU, the 4G standard developed by 3GPP is the LTE-Advanced. The first commercial LTE network was launched in late 2009,

[90] See Prat and Valletti (2003) for an analysis of the issuing of 3G licenses in the EU.

[91] 4G standards include the requirement that 1) it be based on an all-IP packet switched network; 2) it is interoperable with 2G and 3G standards; 3) it offers peak data rates of up to approximately 100Mbit/s for high mobility, such as mobile access, and up to approximately 1Gbit/s for low mobility, such as nomadic/local wireless access; 4) it dynamically shares and utilizes the network resources to support more simultaneous users per cell; 5) it supports a scalable channel bandwidth, between 5 to 20 MHz, optimally up to 40 MHz.

although the final specifications of the IMT-Advanced were not announced until 2012.[92]

LTE enables download speeds of up to 150 Mbps and rates of up to 50 Mbps to upload data, a much higher speed than that offered by the 3G standard, and similar to that of the ADSL. These features allow video conferencing, the sharing and downloading of files (such as pictures), a range of applications and high definition audiovisual contents. The standard also significantly reduces latency compared to 3G, which is essential for applications that require real-time responses, such as network games.

2.2. Mobile broadband's false start in Spain

To meet the objectives of the EU-2020 Strategy, in 2010 the EC reserved the 790-862 MHz band for the deployment of 4G technology. This band, known as the "digital dividend", had to be released across the whole of Europe following the transition from analog to digital television ("analog switch-off"). The reasons for refarming the 800 MHz band to mobile operators lay in the fact that these frequencies would improve the quality of mobile broadband in motion, boost coverage in large buildings and cover a larger part of the territory at a lower cost.[93]

In countries such as Germany, the Netherlands, Portugal and Sweden, mobile operators started to use the 800 MHz band in 2012. In Spain, the Ministry of Industry presented a Royal Decree in 2009 assigning the liberated frequencies between 790 and 862 MHz, and also that of 190 MHz which was free in the 2.6 GHz band, to mobile telephony.

In the summer of 2011 the frequencies in the 800, 900, 1800 MHz and 2.6 GHz bands were allocated to mobile operators. Ninety percent of the frequencies were issued by auction and the rest by beauty

[92] In 2010, the ITU declared that the candidate standards for 4G, such as LTE, could start to be commercialized as 4G standards. Nevertheless, technically LTE is a transitional standard.

[93] Although the whole spectrum can be used for any mobile technology, the propagation of electromagnetic waves is better in low frequencies in the interior of buildings. In contrast, high frequencies on the 2.6 GHz bands have a greater capacity and are more suitable for areas with a high concentration of users.

contest. Telefónica, Vodafone and Orange obtained the maximum allowed frequency at 800 and 900 MHz by auction. However, a block remained unassigned in the 'best' 800 and 900 MHz frequencies. The fact that Yoigo did not bid for them was seen as an indication that it had resigned itself to becoming a national operator that could compete with the other mobile network operators (MNOs). Other candidates for these frequencies included Jazztel and ONO, the new entrants in fixed telephony with a national presence. However, neither operator made a bid for this band, due it would seem to the high reserve price set at auction and the cost of infrastructure deployment. In addition, Orange and Yoigo were granted access to 900 MHz and 1800 MHz frequencies respectively having been selected via beauty contest.[94]

Although the frequencies were allocated in 2011, it was expected that operators would not start using the 800 MHz frequencies until early 2015 due to delays in the reconfiguration of the Digital Terrestrial Transmission (DTT) market. In December 2012, the Supreme Court declared the Council of Ministers agreement of 16 July 2010, by which TV channels were awarded to Atresmedia, Mediaset, Veo TV and Net TV, void, on the grounds that the channels had been allocated without complying with the mandatory public tender as provided for under the new General Law on Audiovisual Communication. The ruling forced the government to restructure the DTT market.[95]

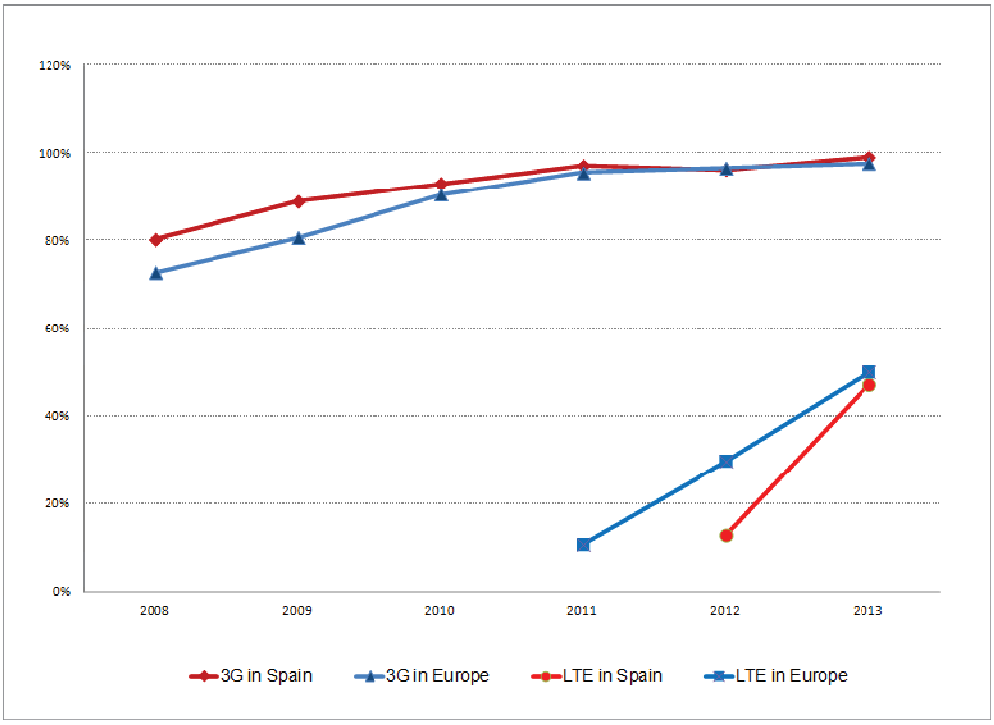
In May 2014 the Supreme Court decreed the closure of nine television channels and in September a new DTT Technical Plan was launched. The plan assigned 30 percent of the frequencies used by national private television to increase the offer of the existing channels. In addition, 20 percent of radio frequencies were reallocated to 4G mobile services.

---

[94] Movistar, Vodafone and Orange paid more than 1,647 million euro for the frequencies, while the cable operators paid 24 million. Jazztel, Euskaltel, R, TeleCable and Telecom CLM also invested in the spectrum, but in much smaller amounts.

[95] In July 2013, the EC gave Spain authorization to delay the allocation of the 800MHz frequencies until 2014. The Commission also accepted a postponement for Cyprus, Lithuania, Hungary, Malta, Austria, Poland, Romania and Finland, but refused derogations in the cases of Slovakia and Slovenia.

Figure 2: 3G and 4G technologies coverage in Spain and in the EU-27



Source: European Commission

A further explanation for the delay in the reallocation of frequencies was the need to retune TV antennas on buildings throughout the country. The previous socialist (PSOE) government estimated that this operation would cost about 800 million euro, and decided that it should be paid for out of the State budget given the poor planning involved in the launch of DTT. However, the new DTT Plan modified this project and reduced the cost of retuning to 286 million euro.

Interestingly, while Spain and other countries are in the process of releasing the 800 MHz band, the EC has begun to evaluate the possibility of refarming the 700 MHz band (Ultra High Frequency Spectrum) for the use of mobile communications so as to fulfill the goals of the Digital Agenda. The creation of this second digital dividend may once again impact the interests of DTT operators since they would be limited to the 470-690 MHz band of frequencies. This policy would also have a greater impact in Spain than it would in other European countries, as the DTT market share is very high relative to other audiovisual platforms such as cable or satellite.

2.3. First 4G commercial offers

The delays experienced in refarming the spectrum did not however prevent some Spanish operators from launching their 4G services in the 1800 MHz and 2.6 GHz bands. In May 2013, Vodafone started to provide 4G services in seven cities (Barcelona, Bilbao, Madrid, Malaga, Palma de Mallorca, Sevilla and Valencia) and the company launched a large marketing campaign to promote the service. In July, Yoigo and Orange responded with similar launches, making the service available in Spain's main cities and gradually expanding their coverage. When the service was first launched, some operators charged higher tariffs for the 4G plan than for the 3G plans, but they subsequently eliminated these additional costs.

Initially, Movistar opted to wait for the allocation of the 800 MHz frequencies before launching its 4G service, but on seeing its rivals launch their offers, Movistar sought a network sharing agreement with Yoigo. In this way, Telefónica and Yoigo started to sell fixed-mobile bundles of fibre and 4G networks, maximizing the latest generation fixed and mobile broadband technologies of both operators. In parallel, Movistar now deploys its own network.[96] According to the CNMC (2014d), in 2013, of the total number (5,866) of 4G base stations installed, Yoigo accounted for 33.2 percent, Orange 27.1 percent, Vodafone 20.3 percent, and Movistar 19.3 percent.

In the sections that follow we discuss Spain's mobile broadband service in greater detail. First, we examine the market structure, and then we evaluate the evolution of competition and prices.

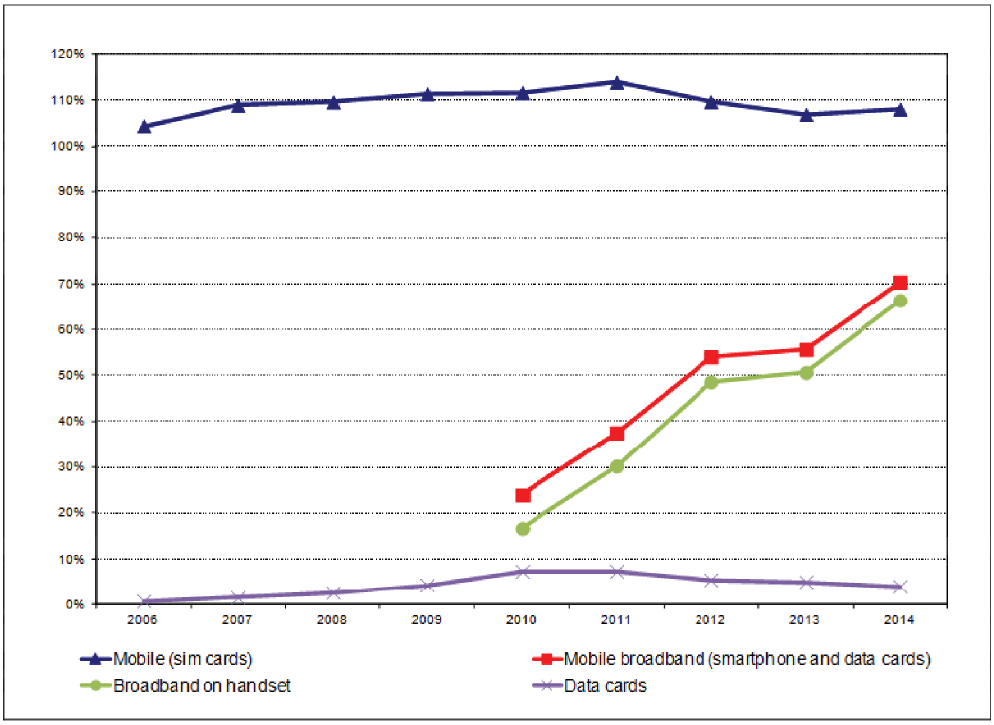
---

[96] The agreement allows Movistar to offer its 4G services over the Yoigo network while in return Yoigo is able to commercialize Movistar's multi-play plans (voice and broadband, either ADSL or fibre). In addition, Yoigo can continue to use Telefónica's transport network for 2G and 3G technologies. In November 2013, the CNMC opened disciplinary proceedings in order to analyse the possible anticompetitive implications of the Telefónica and Yoigo agreements.

3. Spain's mobile broadband market structure

In 2012, after several years of slow growth, the penetration of mobile telephony[97] declined slightly and did not increase again until July 2014, when it reached 109.2 percent (50.7 million lines), a similar level to that recorded in 2007 (Figure 3). This reduction in the penetration rate was largely attributable to the decline in the residential sector, which was hit hard by the economic crisis and rising unemployment. As a result, many consumers opted to unify their communications services under a single number and so stopped using second lines. At the same time many companies and institutions reduced the number of mobile lines available to their employees. It should be stressed that this phenomenon occurred in parallel with a decrease in voice traffic and the introduction of lower tariffs, which significantly shrank carriers' income. Thus, in 2007 while total mobile earnings amounted to 14,103 million euro, in 2013 this figure had fallen to 7,576 million, a similar total to that achieved in 2012.

Figure 3: Penetration of mobile telephony services in Spain

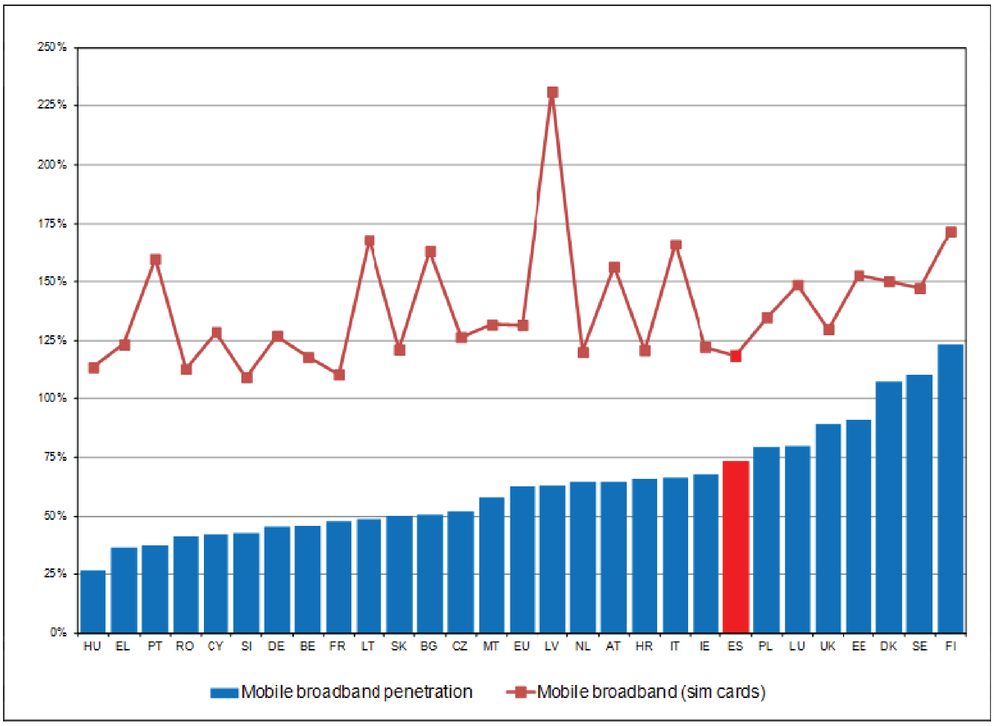


Source: CNMC, annual reports

[97] Mobile service penetration is defined as the number of active SIM cards per 100 people.

Compared to its EU-28 counterparts, Spain has one of the lowest levels of mobile penetration in Europe, which is almost certainly a reflection of the high prices that have traditionally been charged throughout the country (Figure 4).[98] Yet, interestingly 70 percent of mobile contracts in Spain are postpaid, a higher proportion than in many other European countries.

Figure 4: Mobile broadband penetration (January 2014) and active SIM cards in Europe



Source: European Commission

Mobile broadband evolution differs from that of all other telecommunications services. The number of mobile lines providing Internet services on smartphones has grown at a rapid pace in recent years, reaching 70.4 percent of the population (30.9 million lines) by the first quarter of 2014. This growth can be attributed to the success of mobile applications among the population and by the continuous price reductions implemented in recent years. Indeed, revenues from mobile broadband have grown at a healthy rate, but they do not offset the poor performance recorded by all other communications services (see Figure 1). It should also be highlighted that the rate of mobile broadband penetration in Spain is above that of the EU-28

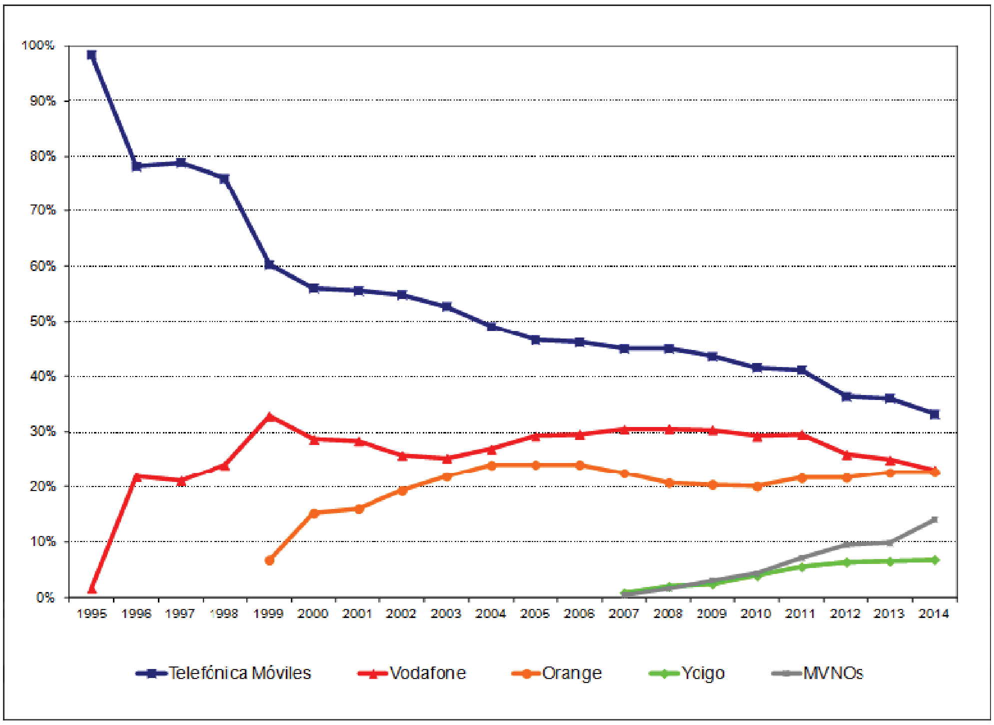
[98] See EC reports (2012a, 2012b, 2013) and OECD (2011, 2013).

average, but the country has lost positions in the ranking of service implementation. Thus, in January 2014 penetration in Spain stood at 73 percent, compared to an average of 63 percent for the countries of the EU-28. The countries heading the ranking of mobile broadband penetration are Finland, Sweden and Denmark, where the rate exceeds 100 percent (Figure 4).

At the same time, the number of Internet mobile connections (datacards) using USB modems/dongles increased significantly until summer 2011, when they reached 3.6 million lines, but subsequently this figure slumped to just 1.8 million in July 2014 (Figure 3). These results suggest that Internet dongle plans became obsolete with the emergence of smartphones, tablets and laptops with integrated SIM cards.

In recent years, the intensification of competition fostered by the implementation of regulatory policies, the increase in the number of operators and technological convergence has transformed the mobile market structure. The total number of lines operated by the two main companies, Movistar and Vodafone, has fallen steadily while the number of customers signed up to Orange (the third largest operator) has increased slightly (Figure 5). At the same time, the most recent market players, Yoigo and the other mobile virtual network operators (MVNOs) have increased their market share significantly since entering the market, and together accounted for 23 percent of all lines in July 2014. In April 2013, for the first time in history, the four MNOs lost subscribers, while the MVNOs as a whole won lines. Thus, the Spanish market has a similar structure to that of the main European markets. According to Ofcom (2014), in 2013 Movistar had a 38 percent market share of connections, while in France the leading operator had a 36 percent share, in Italy 33 percent, in Germany 32 percent and in the UK 31 percent.

Figure 5: Operators' market shares by lines of mobile telephony in Spain



Source: CNMC, annual reports

The operators' market shares of mobile Internet vary slightly with respect to those of mobile services (voice and Internet) combined. According to the CNMC, in the first quarter of 2014, Movistar had a market share of 33.2 percent of mobile lines, 31.8 percent of which were mobile broadband. Elsewhere the respective shares were: Vodafone - 23.1 percent and 24.3 percent; Orange - 22.7 percent and 22.1 percent; Yoigo - 6.8 percent and 9.3 percent, and the MVNOs - 14 percent and 12.3 percent. Thus, the mobile Internet market shares of each operator are similar to their broadband shares except in the case of Yoigo, which has a relatively larger broadband share. It should be stressed, however, that if we consider the revenues obtained by each operator or the traffic generated, the market is considerably more concentrated. Additionally, Movistar and Vodafone have a higher number of postpaid customers than the rest of the operators. This is significant because these customers are usually higher consumers than their prepaid counterparts and so contribute more to the operators' revenues and traffic.

Finally, one of the principal indicators for assessing the state of competition is switching. Since most consumers already have a landline and a mobile line, the operators' primary strategy for obtaining more customers is by poaching them from their rivals by, for example, lowering their prices. In June 2012, CMT approved a measure that shortened the period required to make effective a mobile line portability request from four business days to just one. This change in the regulations has induced a higher switching rate. In 2013, for example, over 160,000 landlines and over 560,000 mobile numbers were switched each month. The operators that have benefited most from this type of policy are the new entrants, Yoigo and the MVNOs (Figure 6).[99]

In a study drawing on Spanish household panel data, the CNMC showed that in 2013 the percentage of individuals who changed mobile operator rose to 17.2, higher than the 11.7 percent recorded in 2012 and the 14.4 percent in 2011.[100] The increase affected changes in both postpaid (up to 20.7 percent) and prepaid contracts (up to 8.3 percent). In the former case, this result can be attributed to the new contracts offered in the fixed-mobile bundles. The reason most often cited for changing operator was a reduction in the bill (64.4 percent), obtaining a new smartphone by taking advantage of a special offer (24.8 percent), dissatisfaction with the service (24.3 percent) and the search for simpler tariffs (19 percent), among others (CNMC, 2014c).

The latest events in the market provide evidence of a reconfiguration, the consequences of which have yet to be felt. Until recently four MNOs offered 3G services via their own networks, while being obliged to rent out their networks to the MVNOs. A total of 24 MVNOs (some of them with a majority participation of an MNO)[101] had entered into agreements with the MNOs to offer 3G services. The market entry of the MVNOs in 2007, the regulation of termination rates and the economic crisis, among others, meant all operators had to compete in terms of price, although several MVNOs opted to focus their service provision on specific groups of consumers. Among the entrants, Yoigo has played a prominent role, developing a different trade policy to that of the other MNOs. At the same time, ONO and Jazztel have entered the mobile market by acting as MVNOs and so are

[99] 674,720 users switched operator in January 2014, the highest number ever, according to the CNMC monthly report.

[100] In fixed telephony the percentage of customers requesting portability in 2013 was 15.4, a record of 1.9 million transfers.

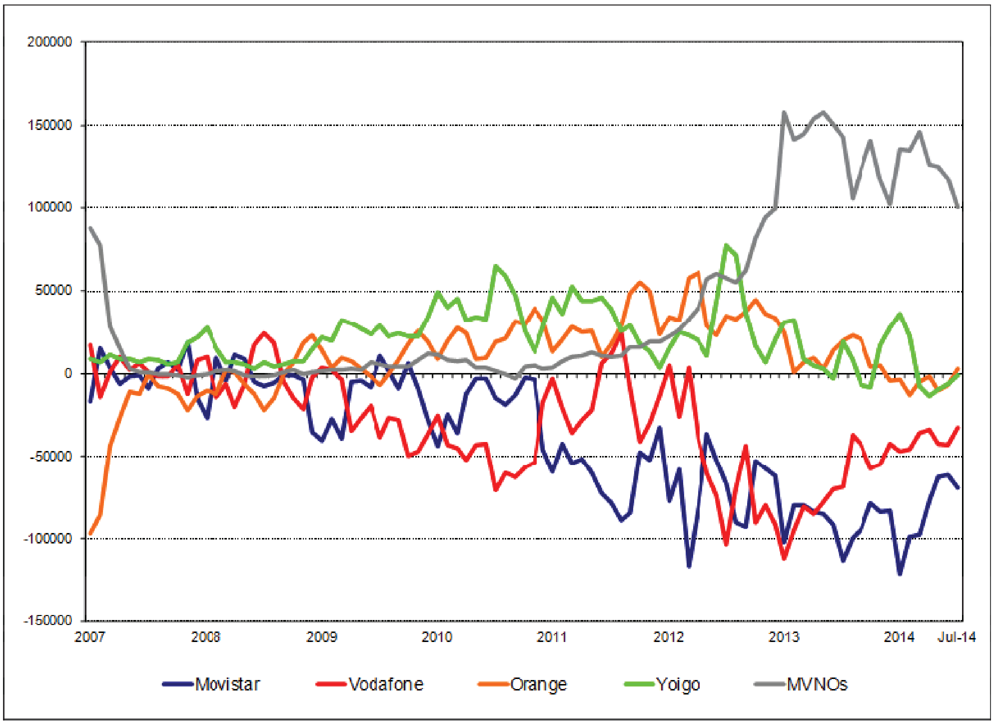
[101] For instance, Movistar acquired Tuenti in 2010, Orange launched its "low-cost brand" Amena in 2012 and bought Simyo in the same year, and Euskaltel has had an agreement with RACC mobile since 2009. In 2012, almost 60 percent of the MVNOs' revenues were generated by special international tariff plans.

able to offer both fixed and mobile services. Thus, various operators commercialize fixed-mobile bundles of both fixed and mobile platforms, and this has served to boost competition.

It is still too early to determine whether the recent launch of 4G is likely to affect the way the market works. To date, the only MVNO which has negotiated the use of the MNOs' 4G network is Pepephone. In February 2014 this operator broke its wholesale agreement with Vodafone in favor of Yoigo after failing to reach an agreement to use Vodafone's 4G network. However, the alliance with Yoigo did not materialize as Yoigo did not receive permission from Movistar to sublet its network. Finally, however, Pepephone reached an agreement with Movistar to offer 4G by the end of 2014. In the forthcoming months, it will be interesting to examine whether it proves equally difficult for other MVNOs to reach agreements with the MNOs, since competition in the market could be undermined if agreements to use 4G networks are delayed.

Technological convergence and market concentration have been particularly intense in Spain. The arrival of 4G coincided with a number of acquisitions on the part of Spanish operators as part of their strategy to create global operators capable of commercializing fixed-mobile bundles. In 2014, Vodafone bought ONO while Orange launched a public bid for Jazztel. These acquisitions should enable the operators to strength their position in the fixed broadband sector. It should be stressed that ONO and Jazztel had been posting very healthy results thanks to their offering deals that bundled fixed and mobile services together, while acting as MVNOs to provide the mobile services. Regional cable companies, such as R Cable and Euskaltel, have followed a similar strategy gaining a good customer base and acquiring mobile 4G licenses for their areas.

Figure 6: Monthly evolution of the net number of mobile lines by operator in Spain



Source: CNMC, monthly reports

A further aspect that might affect the market is the possibility of operators reaching agreements on infrastructure sharing and co-investment in LTE network deployment, such as that signed between Yoigo and Movistar in 2014. According to CMT (2013), both the EC and the NRAs are in favor of these agreements when they involve the sharing of passive infrastructure (e.g., sites and antennas), as has been the case for years. However, in the case of sharing active infrastructure (e.g., radio networks, roaming and national roaming access), it is essential to strike the right balance between cost reductions and the negative impact on competition. An active sharing strategy means that an operator can host customers on its network from other operators that do not have licenses for these frequencies or which have yet to deploy their infrastructure. Similarly, operators might pool their networks in order to access them interchangeably. The crucial element here is whether these agreements might induce operators to pursue other anti-competitive agreements.

4. Competition and tariff structure

The Spanish mobile market has long been characterised by an absence of competition as evidenced by the prices charged in Spain compared with those in the countries of the EU or OECD. A possible explanation for this situation is that in the nineties regulation was not particularly strict and the main objectives sought were to guarantee the operators' profitability and to incentivize investment. Indeed, in 1998 Movistar retail price regulation was abandoned as there were just two operators in the market. The Spanish authorities expected that as the market matured, competition would intensify and this would discipline prices. When in mid- 2000 it was evident that this was not happening, various policies were implemented to foster competition, on many occasions at the instigation of the European Institutions.

One regulation that has proved especially effective in fostering competition is the reduction of mobile termination rates (MTRs). CMT has progressively reduced the MTRs payable by operators when they initiate a call that terminates in a rival network ("glide path"). Following EC recommendations, the termination prices charged by the four MNOs have been limited to 1.09 euro cents per minute since July 2013.[102] In addition, the previously asymmetric MTRs have been changed for fixed MTRs across all operators. This measure has had the effect of reducing the number of off-net calls and of narrowing the gap between on-net and off-net calls.[103] As a result, the number of customers that an operator retains in its network becomes less relevant as prices are fixed. This means that entrants can offer more competitive tariffs at rates similar to those charged by the incumbent carriers (Calzada and Estruch, 2013). Moreover, this convergence of on-net and off-net prices might have had an influence in the appearance of unlimited plans.

The other policy that has had the greatest impact on competition is, without doubt, the entry of the MVNOs. The emergence of Xfera (later Yoigo) as the fourth operator in 2000 was expected to intensify competition in the Spanish market, but it was too late for this operator to set up a GSM network (even though it might have used national roaming) and it was too early to deploy the

[102] In 2012, CMT conducted an analysis of mobile termination calls in mobile networks and concluded that all the MNOs and 'complete' MVNOs (ONO, DigiMobil, FonYou, Euskaltel, TeleCable, R, Lycamobile, Jazztel and Simyo) had significant market power.

[103] On-net calls are those which originate and terminate in the same operator's network, while off-net calls are originated and terminated in different networks.

UMTS network (this technology not yet having been developed sufficiently). In addition it wasted a number of valuable years in which it might have strengthened its position because of the "dotcom crash" of 2001 and the regulation of the MVNOs. Finally, in 2006, CMT obliged the three established mobile operators to lease their networks to new competitors. This favored the entry of Yoigo, who reached an agreement with Movistar to use its network in those areas in which its own network had not yet been deployed. In the years that followed numerous MVNOs set up their new commercial practices thus stimulating price competition.

A final factor – in this case unrelated to the market, but one which accounts for the intensification of competition – is the economic crisis that has afflicted Spain since 2008. The crisis has meant that households and firms have sought to optimize their expenditure and to seek out the cheapest tariffs best suited to their needs.

4.1. New commercial strategies: service bundling and fixed-mobile bundles

In the last few years the telecom operators have adopted new commercial strategies in their battle to win new customers and build customer loyalty. One of these strategies is to sell bundles of traditional voice and messaging (SMS) services with the Internet. Bundling has a number of advantages for customers: first, it typically includes price discounts, but it also means that customers only need a single customer service contract, and so they can control more easily their expenditure with a single invoice as well as control their total expenditure in the communications services.[104]

In 2013, mobile penetration reached 50.2 million lines in Spain. Of these, 31.4 million corresponded to lines with Internet access and 18.4 million lines were bundles of data traffic with other services, generally voice. According to the CNMC (2014d), between 2012 and 2013 the number of people that bought a bundle that included the broadband service increased by ten million.

---

[104] Bundling constitutes a form of price discrimination that allows operators to segment customers and to extract a higher rent than they would obtain if selling each service separately. Bundling can also generate economies of scale and scope which improve welfare. See Adams and Yellen (1976), Evans and Salinger (2005), McAfee et al. (1989), and Nalebuff (2004).

One of the new contract types that has become most popular are the fixed-mobile bundles. These offer both fixed and mobile voice and broadband services in a single plan and so the operators use both their fixed and mobile networks. In September 2012, Movistar released its fixed-mobile bundle under the name of *Movistar Fusión*, and this was widely adopted by consumers. Indeed, Movistar was temporarily able to compensate for the loss of ADSL and mobile customers that it had been suffering.[105]

Movistar's strategy forced its rivals to respond and a price war broke out. In November 2012, Vodafone and Orange attempted to imitate Movistar's plans, although Vodafone did not include the possibility of contracting a TV service. However, the rival operators' hands are tied to the extent that they can only offer their plans where they have the possibility of providing direct access (local loop unbundling), in other words, where they are not completely dependent on Telefónica's network to offer ADSL. At the end of 2013, Yoigo also launched its fixed-mobile bundle thanks to the cooperation agreement signed with Telefónica allowing it to share their networks. This meant that Yoigo and Movistar charged similar retail prices, since Yoigo's customers could use Movistar's fixed networks and change their mobile tariff to one that was compatible with *Movistar Fusión*. Likewise, ONO and Jazztel started to offer fixed-mobile plans acting as MVNOs for mobile services.

The fixed-mobile bundles have enjoyed great commercial success. At the end of 2012 while there were 1.2 million fixed-mobile plan connections, by the end of 2013 this figure had risen five-fold. These included 5.2 million quadruple plans that group the voice and broadband services provided through fixed and mobile platforms, and 700,000 quintuple plans that also included pay-per-view TV channels.

Overall, in recent years the most established operators in the fixed sector have acquired a greater presence in the mobile sector, and the operators with the highest number of mobile subscriptions have obtained new clients, albeit to a lesser extent in the fixed market. In 2013, Movistar, Vodafone and Orange lost mobile subscribers, and were unable to offset these losses with new customers

[105] Movistar's competitors claimed that it was impossible for them to replicate this plan, given the wholesale price level that Telefónica was then charging them to use its network. But in June 2013 CMT opted to close the case on the grounds of the numerous similar plans that operators had launched since 2012.

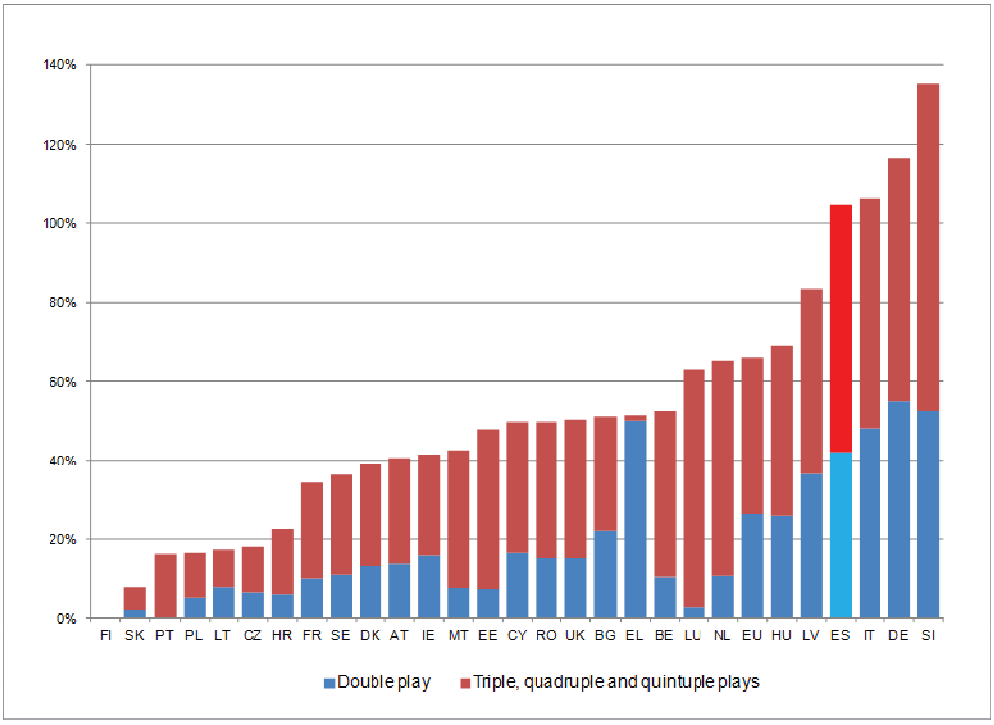
purchasing fixed-mobile bundles. Nevertheless, these operators increased their number of fixed broadband lines, and Orange was in fact the leader in terms of ADSL portabilities. Meanwhile, Jazztel and ONO benefited most from their fixed-mobile bundles, capturing the highest number of mobile subscribers.

As the CNMC (2014a) notes, the potential customer savings associated with fixed-mobile bundles have had a sizeable "carry-over effect". While in the third semester of 2012 37.2 percent of households with fixed and mobile access had all their telecoms services with a single operator, by mid-2013 this percentage had risen to 44.6 percent. Surprisingly, the CNMC report shows that household expenditure remained similar at the "aggregate level" regardless of whether customers contracted the fixed and mobile services with a single or with several different operators; however, significant differences were detected between households in terms of their expenditure patterns.

Figure 7 shows that Spain is one of the four European countries with the highest proportions of bundled communication services, behind Italy, Germany, and Slovenia. Furthermore, Spain is second only to Slovenia in terms of the greatest penetration of triple packages. EC data reveal the sharp rise in the number of lines that are bundles of two or more services. Thus, while in 2012 the penetration of bundles stood at 71 percent, by 2013 it was recorded at 105 percent. More specifically, bundles of three or more services jumped from 40 percent in 2012 to 63 percent in 2013; against 31 and 42 percent in the case of double plays.

Finally, the other commercial practices that date from 2013 are the elimination of minimum contract duration for postpaid plans and the decision taken by some carriers (including Movistar) to sell unlocked handsets. In 2013 some operators also opted to curtail subsidies on all smartphones included with communications contracts, but later owing to the pressures of competition they reintroduced these subsidies. These changes together with price reductions account for the record number of customers switching operators in this period.

Figure 7: Penetration of bundles of communication services in the EU-28, July 2013



Source: European Commission

4.2. Price analysis

The intensification of competition has been an important driver of mobile prices, including those of mobile broadband services. Figure 8 shows that in Spain the average revenue for each mobile line (ARPU, average revenue per user) was halved between 2006 and 2014, falling from 59 to 29 euro per connection and quarter. Likewise, Figure 8 reveals that these reductions were most marked in the case of postpaid contracts. Furthermore, in 2013 the average revenue per minute fell 27 percent for postpaid and 20 percent for prepaid contracts.[106] According to the CNMC (2014c), Movistar and Vodafone have drastically reduced their tariffs in response to the loss in their customer base to the new entrant operators.

In order to have a better overview of the level of competition in Spain, it is

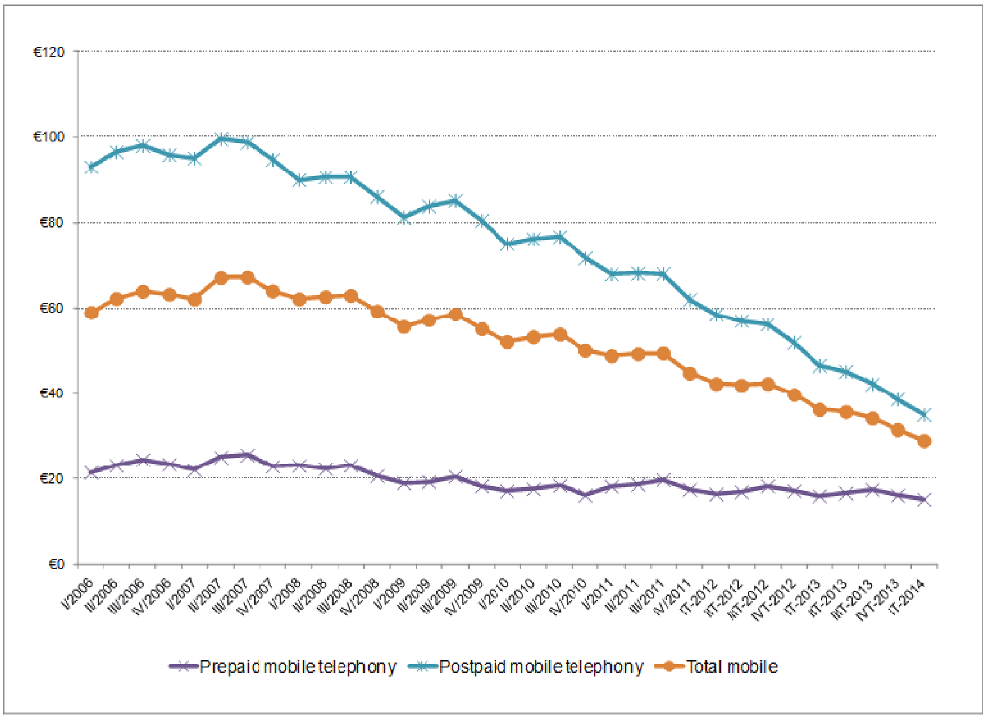
[106] This fall in prices has fostered consumption. In 2013, the voice traffic increased by 34% and data traffic by 115%. However, the number of SMS hardly changed (CNMC, 2014c).

useful to compare Spanish prices with those charged in the rest of Europe. For this purpose, the OECD has developed a methodology for benchmarking mobile telephony prices. The OECD calculates baskets of 30, 100, 300 and 900 calls in addition to text messages distributed in peak and off-peak times as made by a representative consumer. Figure 9 shows the prices for intermediate consumption, that is baskets of between 100 and 300 calls, in August 2012. For baskets of 100 calls, Spain has the highest prices behind only Italy and Hungary, and for baskets of 300 calls Spain has the highest prices behind Hungary, the Czech Republic and Portugal. These results suggest that there is still room for price reductions in Spain. At least, to guide regulatory policy in the mobile sector there would appear to be a need to investigate in detail the factors that account for the differences in prices between Spain and the rest of Europe.

In the case of mobile broadband, Figure 10 shows the quarterly evolution of ARPU for postpaid and prepaid mobile broadband lines between the first quarter of 2012 and 2014. In this period, there was a 24 percent reduction in the average total income, which reflects the intensification of competition.

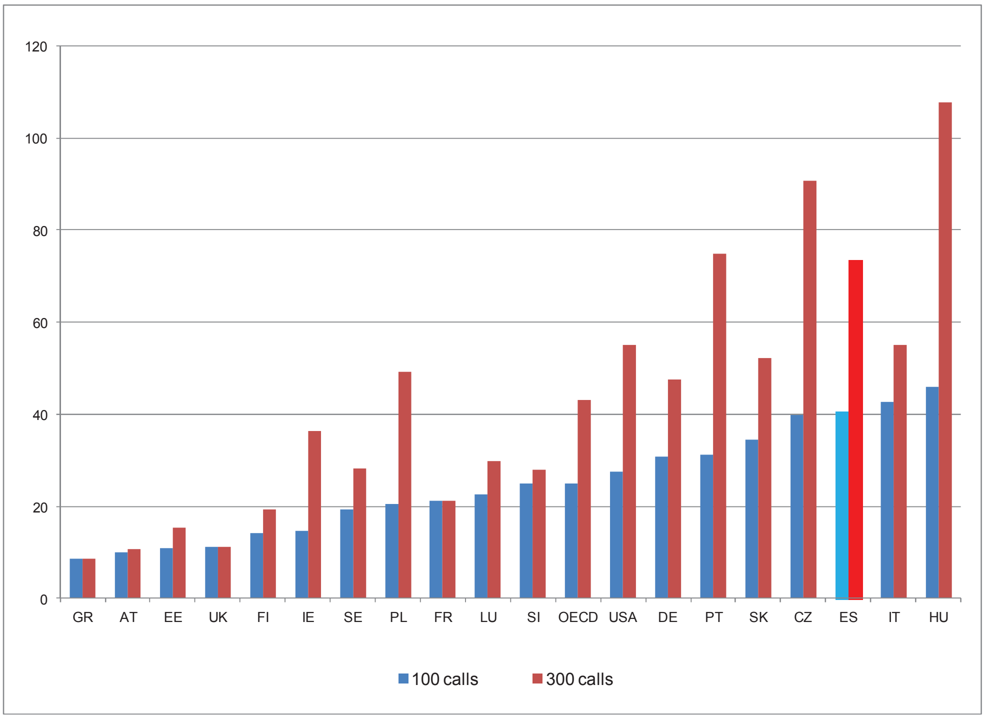
Finally, Figure 11 also compares the prices charged in Spain with those charged elsewhere in Europe. This figure uses data from the ITU to plot the minimum prices (in $ adjusted by power purchasing parity, $PPP) incurred by a consumer contracting a smartphone plan with 500 MB of download volume in the EU-27; most of these offers are postpaid. Figure 11 reveals that in 2013 the prices charged for mobile broadband in Spain were the sixth highest behind Malta, Ireland, the Czech Republic, Bulgaria and Cyprus. These data provide a snapshot of the average consumer's mobile broadband use in Europe, but they offer various insights into the differences between Spain and its European counterparts.

Figure 8: Quarterly evolution of ARPU in mobile telephony in Spain



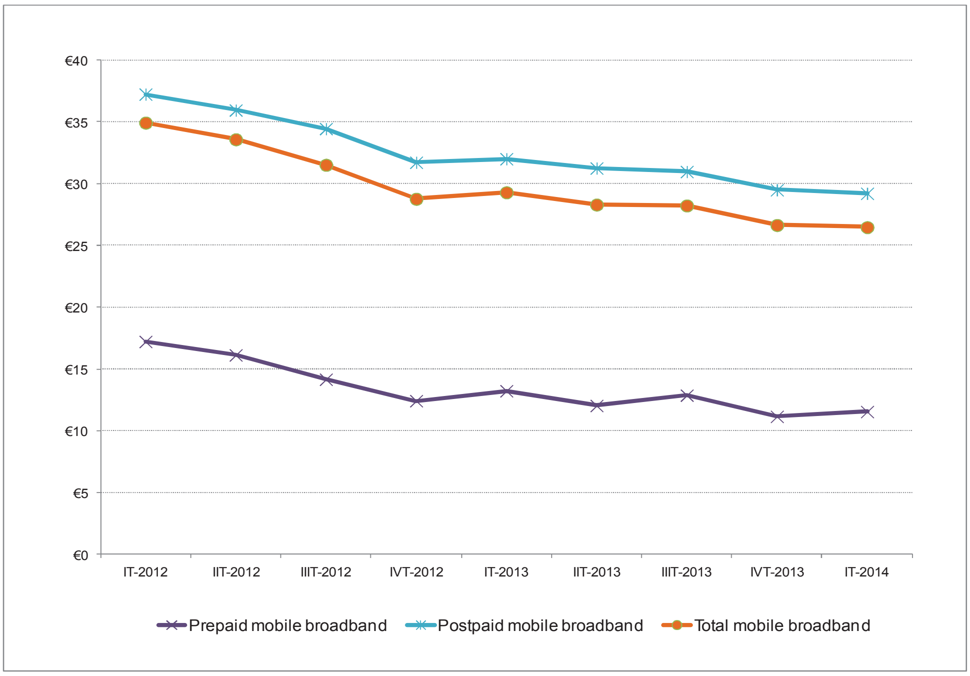
Source: CNMC, quarterly data

Figure 9: Prices of mobile calls, August 2012 (VAT included, $PPP)



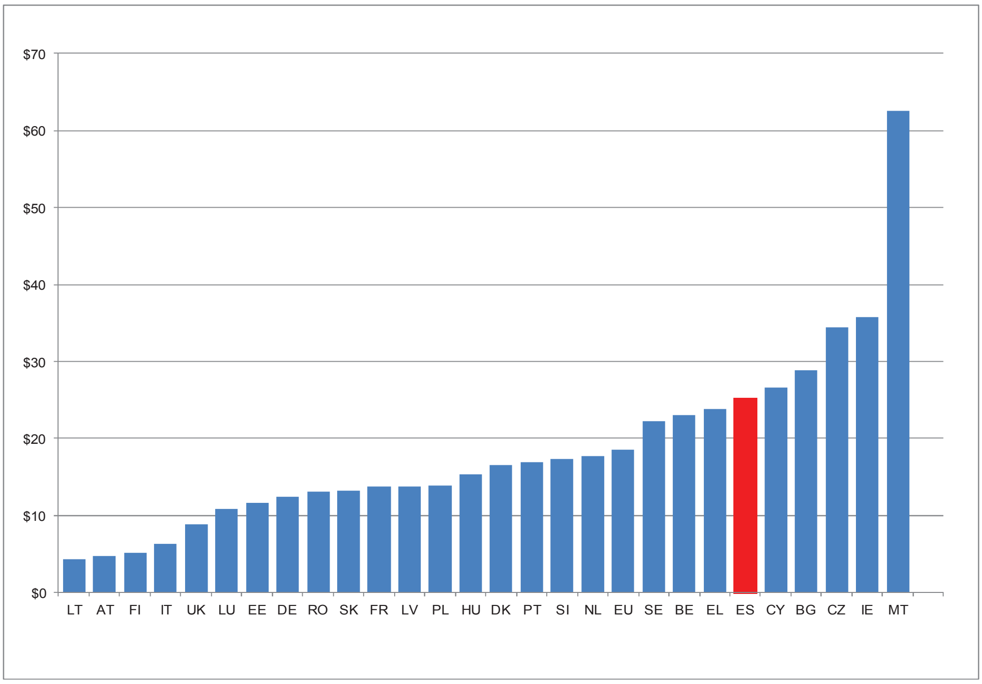
Source: OECD

Figure 10: Quarterly evolution of ARPU in mobile broadband in Spain



Source: CNMC, quarterly data

Figure 11: Minimum prices ($PPP) of mobile broadband (smartphone) in the EU-27, 2012



Note: The plans in Germany, France, Poland, United Kingdom and Czech Republic are prepaid plans. **Source:** ITU, *Measuring the Information Society 2013*

4.3. Spanish mobile broadband plans

In this section, we analyse the characteristics of mobile broadband plans for smartphones in the Spanish retail market. Our study is based on a sample of 54 such plans, 35 of which also include a voice minute allowance. The data were collected from the operators' websites in the third quarter of 2014. Almost half the offers are made by Movistar, Vodafone, Orange and Yoigo. The remaining plans are offered by the leading MVNOs in the market: Pepephone, Simyo, Tuenti, MásMóvil and HappyMóvil.

First, the operators' websites classify mobile broadband plans according to whether the customer chooses to set up a monthly direct debit (postpaid) or a pay-as-you-go payment method by recharging the SIM card (prepaid). In both cases, the two main characteristics of mobile broadband plans are the download volume and the number of minutes of call included in the offer. Only a small number of plans are exclusively for navigating on the Internet with a tablet or laptop via a USB modem or MiFi device (mobile WiFi), which confirms the little consumer interest in this type of service. Finally, the operators' plans can include a wide variety of subsidized smartphones or tablets, which in some cases are unlocked, and the plans are usually subject to a fixed-term contract of several months. Additionally, operators frequently discriminate between old and new customers, as well as between prepaid and postpaid customers, in terms of price and handset subsidies.

The MNO and MVNO plans do not present the same technological characteristics and their commercialization strategies also differ. MVNOs do not yet have access to 4G technologies, with the exception of Pepephone who started to commercialize 4G in early 2015. Moreover, MVNO plans have volume allowances that do not, in most cases, exceed one gigabyte. The MNOs, on the other hand, offer several plans with volume allowances in excess of two gigabytes. Interestingly, Movistar competes directly with MVNOs for customers with an average or low consumption pattern via its MNVO company, Tuenti. It should be stressed that none of the plans provides unlimited Internet usage, possibly so as to avoid arbitrage.

Most of the MVNOs offer plans that provide volume allowances of exactly (or around) one gigabyte and which bundle this data usage with voice minute allowances. MVNOs also have several plans for low usage consumers, i.e., below 500 MB. In contrast, MNOs sell plans with higher volume allowances and focus more specifically on customers who are intensive users of the Internet (most of these plans have volumes with a capacity over 500 MB). For instance, Orange and Vodafone, respectively, offer up to five and six gigabytes of download volume for the mobile broadband tariff on smartphones, compared with the two gigabytes offered by Simyo or 1.9 gigabytes offered by Pepephone.

Some MVNOs, including MásMóvil and Simyo, allow their customers to create a plan by combining a broad variety of data and voice allowances ("menu à la carte"). Others, such as Tuenti, focus on the youngest customer segment, and their bundled services include voice IP. Thus, most MNO plans include data allowances and just a few offer voice only plans (typically prepaid). In contrast, MVNOs have a greater number of voice only offers and Internet can be purchased as an add-on.

Finally, the MVNOs analysed here do not offer any subsidies on handsets when the customer contracts the tariff and also acquires a smartphone. Thus, MVNOs commercialize handsets and the tariff separately so that the price of the plan does not embed any handset cost. It might be the case that MVNOs prefer not to subsidize handsets in exchange for cheaper tariffs, but they may not be able to maintain this policy if competitors start reducing prices.[107] It would be interesting to determine whether Spanish MNOs that enjoy a large market share, or which provide their services in a number of countries, are able to offer better smartphone discounts because of their greater bargaining power with handset manufacturers.

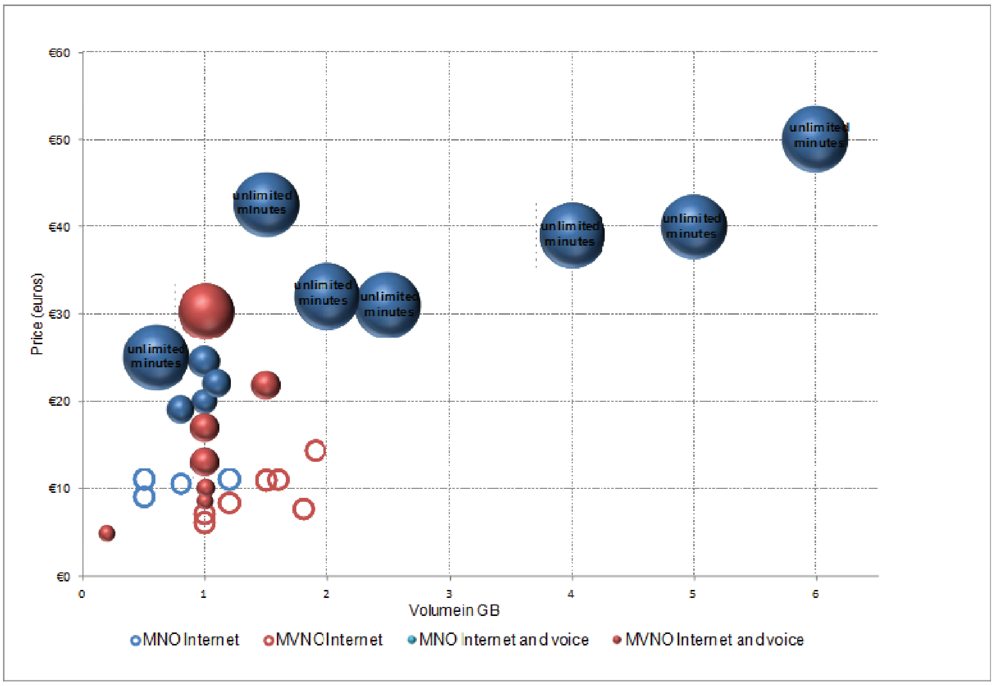
4.3.1. Prices of mobile broadband plans

In this section we examine Spain's mobile broadband plans. It should be noted that the plans are quite heterogeneous in terms of download volume and technology and that operators adopt different commercial strategies, including bundling (allowances of minutes for voice and/or text messages), penalizations when a customer uses all the megabytes included in the plan (a charge per additional megabyte or a speed reduction), a terminal subsidy or

[107] CMT (2013b), in an examination of the handset subsidy policies in 2012, concludes that operators offering discounts on smartphones do not necessarily charge higher prices than operators that do not include a handset in the contract for a mobile service tariff.

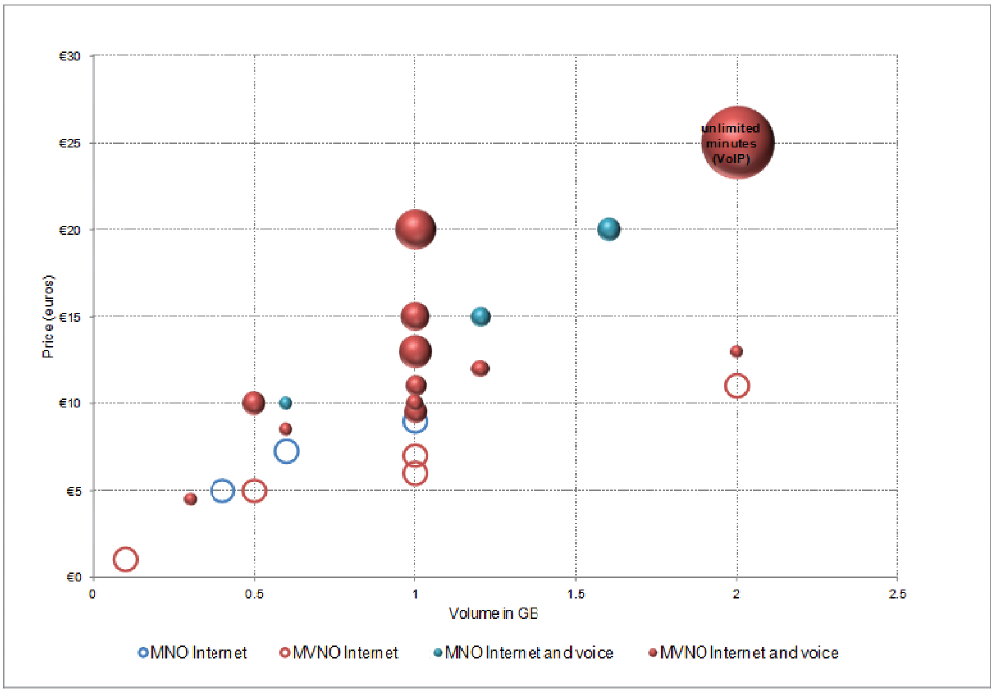
other promotions. Of these characteristics, here we only capture the download volume (in gigabytes) and the number of minutes of calls included in the plans. Figures 12 and 13 show the price of the plans included in the tariff and distinguish between MNO (blue) and MVNO (red) plans. They also distinguish between Internet plans only (circles) and bundles that include broadband and minutes of voice (spheres). The minutes of voice in each plan are captured by the size of the sphere. While a number of plans offer unlimited voice calling, none of the plans offers unlimited data download (the maximum being six gigabytes).

Figure 12: Prices of postpaid mobile broadband plans (Euro, VAT included, October 2014)



Source: Own elaboration

Figure 13: Prices of prepaid mobile broadband plans (Euro, VAT included, October 2014)

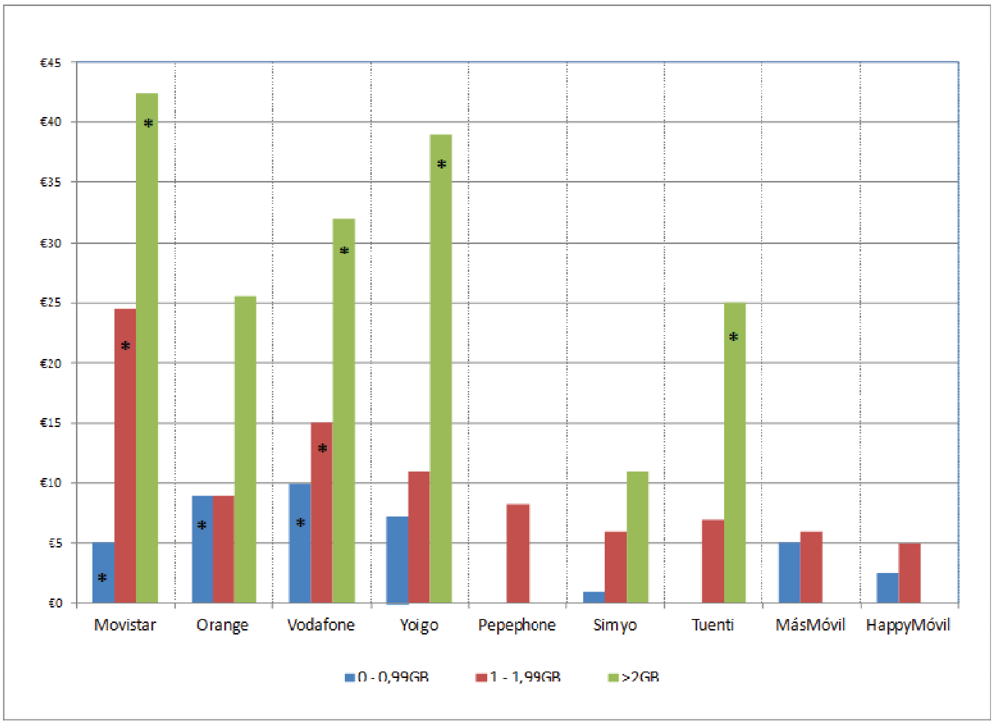


Source: Own elaboration

Inspection of the graphs reveals a positive relationship between price, download volume and number of minutes of voice. It also shows that the prices of postpaid and MNO plans are higher (in an interval of 5 to 50 euro) than those of prepaid and MVNO plans (in an interval of 5 to 30 euro). At the same time, the postpaid and MNOs plans offer greater data volume and longer minute allowances. If, for example, we focus our attention on the one gigabyte volume plans offered by MNOs and MVNOs (that is, 18 of the 54 plans), we see that the latter are cheaper. The plans that provide just mobile broadband (circles) can be supplemented with voice services if the customer makes an additional payment per minute of voice (although in some cases the user only pays a call set-up fee). In the case of the plans that do not bundle broadband with voice minutes, the greater the volume allowance, the lower the price paid per megabyte (i.e., a "non-linear tariff").

Finally, Figure 14 shows the cheapest monthly tariffs of the mobile broadband plans only. Operators not offering an exclusive Internet plan (i.e., the plan also includes voice allowance minutes) are indicated with an asterisk in the graph. Three intervals of download volume are considered: 0 to 0.99 GB (low usage); 1 to 1.99 GB (average usage); and higher than 2 GB (high usage). Broadly speaking, the tariffs offered by MVNOs are always lower than those charged by MNOs. However, Pepephone, MásMóvil, and HappyMóvil do not offer plans with more than 2 GB. In contrast, many of the MNOs' plans include voice allowance minutes.

Figure 14: Minimum prices (euro, VAT included) of smartphone mobile broadband plans in Spain

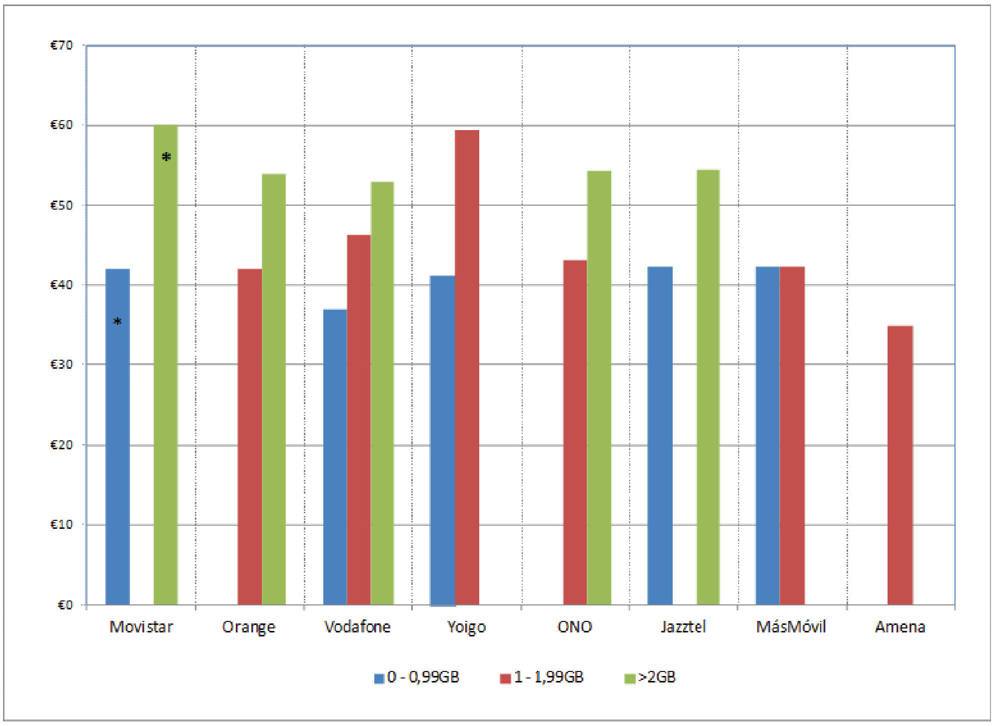


Notes: Pepephone and Tuenti use Movistar network. Simyo, MásMóvil and HappyMóvil use Orange network. *Broadband and voice. **Source:** Own elaboration

4.3.2. Price benchmarking of fixed-mobile bundles

Finally, we analyse the prices of fixed-mobile bundles drawing on a sample of 23 such plans collected in the third quarter of 2014. Figure 15 represents the minimum monthly prices for plans that combine in one bill all the voice and fixed broadband services (including monthly land line rental with VAT) and voice and mobile broadband services. Here again we classify the multi-play service according to the respective download interval (low, medium or high) of the mobile broadband service. An asterisk indicates when the cheapest bundle also includes TV in the price (note that Movistar offers TV in all of its multi-play services). The figure shows the operators that have fixed and mobile networks (e.g., Movistar, Orange, and Vodafone) and the operators with a fixed network that act as MVNOs, e.g., Jazztel (in negotiations with Orange) and ONO (recently acquired by Vodafone). We also include MásMóvil, which commercializes a fixed-mobile bundle thanks to an agreement with Jazztel for fixed services and with Orange for mobile services, and Amena, which is the "low cost" brand of Orange.

Figure 15: Minimum prices (euro, VAT included) of convergent plans in Spain



Notes: ONO use Movistar network and Jazztel use Orange network to provide mobile services. *Broadband and voice. **Source:** Own elaboration

This analysis shows that Jazztel is one of the most competitive operators (in 2013 it grew by 240 percent and reached a customer base of over a million thanks to its fixed-mobile bundles). Nevertheless, the price differences across operators for these fixed-mobile bundles are not as great as those found for the mobile broadband plans above. This might reflect the greater competition between operators to capture new customers by offering multi-play services.

The CNMC's analysis of fixed-mobile bundles identifies small price differences, or differences that are at least smaller than those found between mobile broadband plans. This situation might reflect the competition between operators in the battle to win new customers. The CNMC (2014b) reports that the average price charged in 2012 for contracting fixed and mobile services separately was 57.6 euro per month, falling to 49.3 euro in 2013. By contracting a fixed-mobile bundle customers saved on average 6.5 euro a month.

5. Conclusions

This paper has analysed the evolution and current state of the mobile broadband market in Spain. It highlights the relevance of the progress made by European mobile technological standards for the deployment of mobile broadband services. Thanks to progressive technological innovations, the speeds provided by mobile technologies are rapidly catching up with those of broadband, and it has been possible to develop smartphone applications that are modifying users' communication behavior and handset use.

In recent years, competition amongst mobile operators has grown noticeably. MNOs have had to accommodate the entry of MVNOs, but at the same time the former have created secondary brands that compete directly with the latter for low consumption users. This has led to significant price reductions. However, telecommunications convergence has also changed the operators' business practices, promoting the launch of multi-play services that have been highly successful among consumers. MNOs today seek to attract and retain customers by offering fixed-mobile bundles on a single bill for all telecommunications services.

The intensification of competition and the launch of fixed-mobile bundles have also resulted in the restructuring of the market. Thus, Vodafone has acquired ONO, Yoigo has reached an infrastructure sharing agreement with Movistar, and Orange is negotiating the purchase of Jazztel. In parallel, fixed and cable operators are using the MNOs' networks to offer their mobile services and some have acquired 4G licenses. However, the market restructuring process has created doubts about the future role of MVNOs. To date, MVNOs have been able to use the MNOs' networks when offering their 3G services, but in the forthcoming months MVNOs will have to negotiate the use of new 4G networks.

In recent years, Spanish mobile communication prices have fallen significantly and there has been strong growth in mobile broadband penetration, which is now above the EU average. There can be little doubt that this is the result of the intensification of competition, which has been achieved through the regulatory activity of the Spanish and EU authorities and the increase in the number of operators. The regulation of MTRs has reduced off-net call rates and encouraged the emergence of bundles. At the same time, the entry of MVNOs has increased the number of offers, giving customers a wide choice of commercial offers at prices that are lower than before their entry. Despite this, Spain still stands below the EU average in terms of the penetration of active SIM cards and is one of the countries with the highest prices for mobile services. The main challenge for the future will be maintaining competition in a market that is becoming increasingly concentrated.

References

Adams, W. and Yellen, J., 1976. "Commodity bundling and the burden of monopoly", *Quarterly Journal of Economics*, 90, 475-98.

Bekkers, R., 2001. "Mobile telecommunications standards: GSM, UMTS, TETRA and ERMES", Artech House, Boston.

Bel, G, Calzada, J., and Fageda, X., 2006. "Liberalización y Competencia en España: ¿dónde estamos?", *Información Comercial Española*, Vol. 829, 123-144.

Cabral, L. and Salant, D., 2013. "Evolving technologies and standards regulation", *International Journal of Industrial Organisations*.

Calzada, J. and Estruch, A., 2011. "Telefonía móvil en España: regulación y resultados", *Cuadernos Económicos de ICE*, 81, 39-71.

Calzada, J. and Estruch, A., 2013. "Comunicaciones Móviles en la Unión Europea: tecnología, políticas y mercado", *Papeles de Economía Española*, N.º 136.

Calzada, J. and Martínez-Santos, F., 2014a. "Broadband prices in the European Union: Competition and commercial strategies", *Information Economics and Policy*, 7, 24–38.

Calzada, J. and Martínez-Santos, F., 2014b. "Competencia en el Mercado de banda ancha móvil en España", *Cuadernos Económicos del ICE*, 88, 97-129.

CMT, 2013a. Informe Económico Sectorial 2012. Comisión del Mercado de las Telecomunicaciones.

CMT, 2013b. "Estrategias de venta de terminales y precio de los servicios móviles", Nota ocasional 7.

CNMC, 2014a. "Efecto arrastre entre las demandas de servicios fijos y de servicios móviles tras la eclosión en España de los paquetes convergentes de servicios fijos y móviles", Documento de Trabajo número 2, Abril 2014.

CNMC, 2014b. "Cambios de operadores de los servicios de comunicaciones electrónicas en el sector residencial en 2013", Documento de Trabajo nº 3, Julio 2014.

CNMC, 2014c. "Informe de seguimiento de las ofertas comerciales de servicios de comunicaciones móviles entre 2012 y 2013", Documento de Trabajo nº 12, Julio 2014.

CNMC, 2014d. "Informe Económico de las Telecomunicaciones y del Sector Audiovisual 2014", Comisión Nacional de los Mercados y de la Competencia.

Crandall, R., Lehr, W., and Litan, R., 2007. "The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data", *Issues in Economic Policy*, The Brookings Institution, No. 6, July.

Czernich, N., Falck, O., Kretschmer, T. and Woessmann, L., 2011. "Broadband Infrastructure and Economic Growth", *The Economic Journal*, 121 (May), 505-532.

European Commission, 2012a. "Digital Agenda for Europe, Scoreboard 2012". Directorate-General for Communication Networks, Content and Technology (DG-CONNECT), Brussels.

European Commission, 2012b. E-communications Households Survey. Report. Special Eurobarometer 381. Directorate-General for Information Society and Media, Brussels.

European Commission, 2013. "The mobile use of the Internet by individuals and enterprises". *Digital Agenda Scoreboard 2013*, Chapter 4, June 2013.

Evans, D. and Salinger, M., 2005. "Why do firms bundle and tie? Evidence from competitive markets and implications for tying law", *Yale Journal on Regulation*, 22, 37-89.

Gabaix, X. and Laibson, D., 2006. "Shrouded attributes, consumers myopia, and information suppression in competitive markets", *Quarterly Journal of Economics*, 121 (2), 505-540.

Galperin, H., 2012. "Prices and quality of broadband in Latin America: Benchmarking and trends", *Economics of Networks eJournal* 4(64).

Gandal, N., Salant, D., and Waverman, L., 2003). "Standards in Wireless Telephone Networks", Telecommunications Policy, 27, 325-332.

Gruber, H., 2007. "3G mobile telecommunications licenses in Europe: a critical review", *Info*, Vol. 9, n.6, 2007, 35-44.

Gruber, H. and Verboven, F., 2001. "The evolution of markets under entry and standards regulation - the case of global mobile telecommunications", *International Journal of Industrial Organisations*, Elsevier, Vol. 19(7), pages 1189-1212, July.

Gruber, H. and Valletti, T., 2003. "Mobile telecommunications and regulatory frameworks", in Emerging telecommunications networks: *the international handbook of telecommunications economics*, volume II, Editor(s): Madden, Cheltenham, Edward Elgar.

Grzybowski, L., 2005. "Regulation of mobile telephony across the European Union: an empirical analysis", Journal of Regulatory Economics, 28 (1): 47-67.

Grzybowski, L., 2008. "The impact of regulation on the retail prices in fixed-line telephony across the European Union", Telecommunications Policy, 32 (2): 131-144.

Grzybowski, L., 2012. "Fixed-to-Mobile Substitution in the European Union, mimeo.

Grzybowski, L. and Dauvin, M., 2014. "Estimating broadband diffusion in the EU using NUTS1 regional data", *Telecommunications Policy*, 38(1), 96-104.

Grzybowski, L. and Liang, J., 2014. "Estimating demand for quadruple-pay tariffs: The impact on consumer surplus", mimeo.

Hillebrand, F., 2013. "The Creation of Standards for Global Mobile Communication: GSM and UMTS Standardization from 1982 to 2000", *IEEE Wireless Communications*, 24- 33.

Koski, H. and Kretschmer, T., 2004. "Entry, Standards and Competition: firm strategies in the diffusion of mobile telephony, *Review of Industrial Organisations*, 26, 89-113.

McAfee, R.P., McMillan, J. and Whinston, M.D., 1989. "Multiproduct Monopoly, Commodity Bundling, and Correlation of Values", *The Quarterly Journal of Economics*, MIT Press, Vol. 104(2), 71-83, May.

Nalebuff, B., 2004. "Bundling as an entry barrier", *Quarterly Journal of Economics*, 119, 159-87.

OECD, 2011. "Broadband Bundling: Trends and Policy Implications", OECD Digital EconomyPapers, No. 175, *OECD Publishing*.

OCDE, 2012. "OCDE Communications Outlook 2011. *OCDE Publishing*.

OCDE, 2014. "OCDE Communications Outlook 2013". *OCDE Publishing*.

OFCOM, 2014. "The European Broadband Scorecard, Research Document", 12 March 2014.

OFCOM, 2014b. "Measuring mobile broadband performance in the UK", Research document, November.

Prat, A. and Valleti, T., 2003. "Spectrum Auctions Versus Beauty Contests: Costs and Benefits", en Mario Baldassarri y Luca Lambertini (eds.), Antitrust, *Regulation and Competition*, Palgrave Macmillan, London.

Sung, N. and Kwon, M., 2011. "An empirical analysis of the state of competition in OECD mobile wireless markets", 22nd European Regional Conference of the International Telecommunications Society (ITS2011), Budapest.

Vogelsang, I., 2010. "The Relationship between mobile and fixed-line communications: a survey", *Information Economics and Policy*, 22(1): 4-17.

Chapter 5

Concluding remarks

This dissertation studies the different aspects of fixed and mobile broadband Internet services from a competition and regulatory policy perspective. The novelty of this research is that it analyses in depth the pricing policies of telecom operators using a set of fixed and mobile broadband plans. First of all, the models developed in the dissertation aim to find how the market structure and regulatory policies implemented in each country may affect the level of prices paid by end-consumers. Secondly, the models also explain the features of each of the plans discussed, which reveal how operators use the heterogeneity of the broadband service to design and establish retail tariffs.

A common finding across the three chapters of this thesis is that regulatory policies which have been successful in promoting entry to the broadband sector have also increased competition and benefited customers by way of price reductions. In this respect, the second chapter shows that the "ladder of investment" theory (Cave, 2006), adopted by European regulatory authorities, has important implications on prices in the fixed broadband sector. This theory shows that, in order to promote sector competition, regulators initially facilitate the access of entrants to incumbents' networks so that entrants only need to make very small investments at first (resale or *bitstream* access). Subsequently, once these entrants have acquired a level of experience and increased their customer base, regulators then create incentives designed to encourage entrants to invest in their own facilities (local loop unbundling access, LLU). This study demonstrates that broadband prices are lower in those countries where entrants have invested in their own facilities and make greater use of LLU access, and higher when they use *bitstream* more intensively. On the other hand, when operators build their own network or compete using different platforms (DSL, cable modem or fibre optic), the study shows that prices are not substantially affected.

The analysis of the mobile broadband sector within the third chapter shows that mobile operators commercialise their plans using multi-tier pricing schemes based on the mobile services' different characteristics. This study reveals that data allowances (gigabyte caps) are a key feature used by mobile operators in the setting of prices. Another relevant finding is that operators usually bundle their broadband plans with a smartphone device, and in cases where popular smartphone brands are provided, customers ultimately pay much more than for SIM-only Internet plans. Finally, regarding the effect of entry, the study shows how mobile virtual network operators (MVNOs) have promoted competition and helped to reduce prices.

The last chapter is a case study of the Spanish mobile broadband sector, which highlights the evolution of the Spanish mobile market towards greater competition and how, more recently, the MVNOs' tariffs and the success of multi-play bundles (four and five play plans) have fostered competition.

It is important to note that the fixed broadband service is analysed during a period when the European fixed broadband market had already reached some degree of saturation and penetration growth rates were decreasing (period 2008-2011). However, the analysis period of the mobile broadband corresponds to an expansion phase (period 2011-2014) of the service. In this context, it can be observed that fixed and mobile broadband plans present very different features and are also commercialised differently. Indeed, operators might modify and adjust their plans' characteristics to cater to an environment of increasing demand in terms of subscribers to communications services, but also of higher demand in terms of traffic (gigabytes) or quality (download speeds). They have done this by creating "innovative pricing plans" (Lee, 2011; Corrocher and Zirulia, 2010) so as to maximise revenues and monetise innovations in technology.

The remainder of this chapter harmonises the most important conclusions of the three chapters which form my dissertation. The final paragraphs of the conclusion mention some further fields of the broadband service that could have been explored further.

Chapter 2. Broadband prices in the European Union: competition and commercial strategies

The fixed broadband plans are highly differentiated in many aspects, but two essential features are the download speed and bundling practices of broadband with voice and/or TV services, all of which have a strong positive impact on prices. In the same vein, download speeds and bundling are used by the national regulatory authorities (NRAs) and international institutions (OECD, ITU, EC and BEREC) to compare the retail access costs of broadband services across countries. Indeed, these bodies use these two parameters to create "baskets" of plans and to compare retail tariffs within each basket.[108] This shows us that the heterogeneity of broadband plans makes it necessary to group plans sharing key features in order to make like-for-like comparisons of the tariffs across operators and countries. It is important to highlight that, while the download speed increases the quality of the service and impacts positively on customer utility, the customers' benefits from bundling remain ambiguous (Evans and Salinger, 2006).

Where the technology is concerned (DSL, cable modem, and fibre), the study reveals that the price paid per Mbps for cable modem and fibre technologies is lower than DSL plans. This is an interesting result in a period of controversy where operators are balancing out the interests of deploying Next Generation Access Networks (NGANs). However, plans using NGANs, such as fibre technologies, are usually commercialised with higher download speeds, hence these plans might be more expensive as a result. This finding is especially important because regulators want to foster the deployment of NGANs, but ultimately this depends on the profits that operators think they can make from investing in them.

The most insightful finding in this chapter sheds light on the effects of regulatory policies on the level of competition in the fixed broadband market. NRAs provide "entry assistance" to new operators by setting access prices at different levels from the incumbent's network according to the "ladder of investment" theory (LOI, Cave (2006)). The regulation of access is described as the competition generated when entrants use the incumbent's network (the incumbent's network is mostly DSL in the countries analysed); this is called intra-platform competition. The results show that retail prices are higher in countries where entrants resale incumbents' plans or use *bitstream* access compared to the countries where operators make a comparatively higher use of LLU. Moreover, the increase in prices due to intensive *bitstream* appears to be much higher compared with the reduction in prices which occurs when entrants use *direct access* (LLU); this might be linked to the possibilities of

[108] "Baskets" are constituted of broadband plans split into bundles, stand-alone offers, and download speed intervals.

greater differentiation and higher quality with LLU.

On the other hand, this study finds little evidence of price changes when entrants build their own network or compete using different platforms (inter-platform competition). Duplicating the incumbent's network at one time is risky and requires high sunk costs. Yet, operators that rely only on their own networks, usually cable modem or fibre, might be competing more in quality products rather than on prices. Moreover, operators in some countries serve different geographic parts of the market. For instance, in Belgium, the Flemish region is mostly served by cable operators, while in the Wallonia region it is predominantly DSL, and while these two platforms do not directly compete, the pricing model considers that they do. This is not captured in the analysis and might affect the result obtained for inter-platform competition, which appears not to create significant differences in prices.

Chapter 3. Pricing strategies and competition in the mobile broadband market

This chapter analyses in depth mobile Internet plans on smartphones using a similar approach as in the previous chapter. This study complements the previous one on fixed broadband, which has not considered wireless broadband technologies. These technologies have experienced significant expansion since the end of the last decade. Operators have adjusted their mobile tariffs from the previous usage, based only on voice and text messages (SMS), to tariffs that charge mainly for data traffic and less for the traditional voice/SMS services.

This study analyses the strategies adopted by mobile operators when they set the prices of mobile Internet plans for smartphones. In the mobile sector, operators have designed multi-tier price schemes so that consumers select a plan according to their usage of both the Internet and phone calls. This allows operators to monetise usage of the mobile service and adapt to competition by segmenting the market. It is found that the price is based mostly on the consumption of Internet rather than voice. Operators only offer a small number of unlimited usage contracts ("all you can eat" data plans) and the majority of plans are commercialised with data caps (volume allowances in gigabytes). The study shows that the prices of plans with data limits are substantially lower than the unlimited data plans. However, customers may be penalised when they end the data cap and plans may automatically charge additional fees or 'overage charges' to continue using the Internet. Indeed, most plans add 'overage charges' when the client exhausts the data cap, and moves the customer to a plan with a new allowance (amount of gigabytes) or to a pay-as-you-go tariff type (per kilobyte/megabyte). In the end, customers which are not aware of these 'overage charges' may end paying higher bills than expected.

The relevance of data allowances in the mobile market contrasts with the fixed broadband service studied in the previous chapter. For fixed broadband plans speed thresholds are used as the main characteristic of the service to segment customers, and most fixed broadband plans are data unlimited, while this is not the case for mobile Internet plans.

There are different reasons why operators use data allowances: i) to segment customers according to their usage so as to maximise their revenues and adapt to competition; ii) to avoid problems of network congestion when many customers are downloading from the Internet; and iii) a third question has been analysed in a paper by Economides and Hermalin (2014) who signal the interest that operators have in establishing data volume caps in order to pressure content providers (e.g.: video-on-demand companies) to lower either their prices or the quality of the content (so that it requires less capacity). Thus, telecom operators are able to extract potential content providers' rents using caps on volume. This is also related to operators' claims against the "network neutrality" approach, which treats all data on Internet services equally. Indeed, by setting data caps, operators are violating the net neutrality principle, as some customers end up paying more when they use Internet services which demand high data volumes (Trinh et al., 2012).

One of the most important contributions of this paper is to identify the operators' "subsidies" when providing a smartphone with the Internet tariff. Operators act as the most important smartphone distribution channel, and offer customers the possibility to buy the smartphone either separately or together with the plan. For instance, given the importance of the operator as a channel through which to sell smarpthones, the manufacturer might wish to provide a significant discount to the mobile carrier, expecting this will incentivise the take-up and popularisation of a specific brand. The evaluation of these subsidies lies in the final effect of several competition forces impacting on the price paid the by the end-client for the smartphone (with the tariff). The potential effects discussed in this chapter are: i) at the wholesale level, the relative bargaining power of the operator versus the handset manufacturer; ii) exclusive contracts between these two market players (Sinkinson, 2014); iii) at retail level, the operators' strategies to use the smartphone as a tool to segment customers with a higher willingness to pay for the mobile service; and iv) to what extent the discounts obtained by the operators are passed through to the end-consumer. The result of the analysis is in line with these market forces, although it does not enable each of them to be quantified separately. However, the analysis reveals that the most in-demand smartphone brands, iPhone and Samsung, imply a lower subsidy to the final consumer compared to other brands which are not so well-established in the handheld-device market. Furthermore, while the price differences between these two brands and SIM-only plans (plans without a smartphone) result in substantial costs, the analysis shows there is no clear evidence of any important differences between plans including "other brands" and SIM-only tariffs.

Compared to the previous chapter on fixed broadband, where there is scope to study the effects of regulatory policies within a market which has been heavily regulated since its beginnings in the 1990s, the mobile broadband market arose only a few years ago (with 3G technologies) and it has not been so heavily regulated to date. In fact, the regulation of mobile broadband arises indirectly from the regulation of prices paid between mobile operators according to the quantity of off-net mobile phone calls (mobile termination rates, MTRs). More recently, in Europe, regulators have encouraged MVNOs to reach agreements with operators with their own network (MNOs), in an attempt to promote entry in the mobile market.

The chapter incorporates, in the final section, the regulatory measures mentioned in the above paragraph along with the level of operators' concentration in each geographic market using a subsample of 20 EU countries. The findings show that the differences in market concentration across the 20 European countries do not correspond with significantly higher prices. As for the regulatory factors that might affect tariffs, MTRs do not seem to have any effect, which might be attributed to the lower contribution of voice services to the tariff, and also to the underlying "glide path" by which operators have been reducing the MTRs and making them converge in recent years. However, the promotion of competition via the entry of new mobile service providers, the MVNOs, appears to have reduced the mobile broadband tariffs. This suggests that the entry of MVNO's promotes competition.

Chapter 4. Competition in the Spanish mobile broadband market

This chapter illustrates how the mobile broadband service has expanded greatly in Spain, achieving a higher than 70 percent penetration rate by the beginning of 2014. This growth can be attributed to the benefits that have accrued from the development of the third and fourth generations of mobile technology and to constant price cuts in the market. Yet, despite these reductions, prices in Spain remain above the European average. The chapter describes the process of technological innovation that has facilitated the emergence of mobile broadband, and the launch of this service in Spain. The commercial strategies recently adopted by mobile operators, including bundling and plans offering fixed and mobile services, are examined. The analysis shows that the presence of MVNOs and the availability of bundled offers have been effective in fostering competition and reducing prices in Spain. It also analyses how the successful release of multi-play bundles (four and five play plans) have promoted market restructuring and concentration.

Firstly, this study explains how harmonisation of standards contributed to the diffusion of mobile services in Europe compared to the US, where different and incompatible standards competed against each other. Also, the "dotcom crash" at the beginning of the 21st century meant that operators ceased their investment in 3G technologies. In Spain, while the launch of 3G services occurred relatively early on, incorrect decisions taken regarding the award and re-farming of frequencies between mobile operators and digital TV channels delayed the launch of 4G, and also increased public spending.

Another relevant aspect is that entry has been essential to increase competition in the Spanish mobile market. New operators appeared thanks to the government issuing of new mobile licenses and the intervention of the EU in helping entrants by setting asymmetric MTRs (lower for small network operators, Yoigo in the Spanish case), and also allowing new entrants without their own network, the MVNOs, to reach agreements with the MNOs to use their frequencies (Calzada and Estruch, 2013). MVNOs have released "innovative pricing plans" that are different from MNOs, and in broad terms have undercut the MNOs' tariffs to grow their customer base (Kiiski, 2006). Some common patterns within MVNOs are that they target low usage customers compared to MNOs. Also, MVNOs commercialised more types of plans, such as only voice plans or voice over IP, and allowed more flexibility over voice and data allowances. Moreover, the MVNOs' tariffs do not subsidise the handset with the tariff, and as yet none of the MVNOs have 4G plans in place (Pepephone should be offering 4G by the beginning of 2015).

To adapt to the intensification of competition, MNOs have also changed their pricing strategies so as not to lose their customer base. At the end of 2012, Movistar released the multi-play bundle *Movistar Fusión,* which grouped fixed and mobile voice, broadband service, and digital TV in a single bill. Rival operators subsequently followed this billing strategy with similar plans after realising that customers were very keen to contract all of their communications services under a single tariff. In fact, before 2012, four or five play bundles did not exist, yet only two years later they accounted for 63% of all bundles (7.6 million multi-play bundles). This shows that commercialisation plays a very important role in increasing the adoption of telecommunications services.

The usage of bundling was a controversial issue when Movistar first launched its multi-play offer *Movistar Fusión*. In fact, at the beginning, rival operators claimed that it was not possible to replicate Movistar's multi-play offers (however, these operators started to launch similar plans soon after *Movistar Fusión*). This raises the question that although the practice of bundling might promote the penetration of the service, it might also be used as an anticompetitive tool in the market. Indeed, an operator with market power in one of the communications services might start commercialising bundles to leverage power in a second service. Thus, bundling might promote competition but could also be considered an anti-competitive practice if the aim of the operator is to force the exit of its rivals, or to prevent entry in secondary markets (Nalebuff, 2004; Mariñoso et al., 2008). Also, from the consumer perspective, some customers might find themselves at a disadvantage when taking out a bundled contract, for instance, if they have difficulty switching all services to an alternative provider.

All in all, we can take certain conclusions from the analysis of the structure and pricing of the mobile market in Spain. The evolution of the market has followed a less concentrated market and higher competition with the emergence of new operators. This has been pro competitive, but at the same time there is a trend that points towards a concentration of mobile and fixed telephony operators, in part thanks to the success of the multi-play bundles which have promoted market concentration between operators using different platforms in recent years (Orange and Jazztel, and Vodafone and ONO). Entrants might be limited by not being able to offer these convergent products, as well as MVNOs not being able to reach agreements with MNOs to deliver 4G technologies. This study signals that it is important to bear in mind these changes in the mobile market so as to allow competition forces to benefit customers.

Suggestions for future research

In this dissertation, unfortunately, we could not analyse fixed and mobile broadband plans jointly in order to take into account the relationship between fixed and mobile broadband tariffs (Sriuan and Bohlin, 2012; Haucap et al., 2014). Also, it would be interesting to better understand substitution or complementarity patterns between mobile and fixed broadband using evidence at consumer level (Nakamura, 2015). Furthermore, in this line of research, it would also be interesting to study the degree of substitution between mobile broadband on smartphone and via USB modem. The latest technological improvements, such as the use of the smartphone as a modem USB ('tethering') with the mobile plan, may well have promoted this substitution, although it remains to be tested empirically.

There are more questions related to this dissertation which might have been examined further, which are left for future research. For instance, bundling is a recurring topic that has been widely studied in the economic literature (Adams and Yellen, 1976; McAfee et al., 1989) but the empirical research on bundling decisions in the telecoms industry might be developed further. Chapter 2 has examined bundling from the supply point of view, and found positive correlations between bundling and the use of direct access (LLU) by entrants. Also, an OECD report (2011) examines and describes bundling in the broadband market from the supply side in OECD countries. However the literature on bundling telecoms services from a consumer perspective is sparse, and it would be interesting to test empirically if the consumers' advantages from buying bundles offsets the drawbacks (e.g. lock-in effects with the telecoms provider). In this respect, there are two related relevant studies that analyse the bundling of TV channels in the cable TV market. The first, an empirical work by Byzalov (2010) is based on a consumer demand choice model for bundles of cable television channels in the US, and finds that requiring cable companies to break up their main packages, allowing consumers to pick individual channels or small "mini-tiers" on an *à la carte* basis, would imply big drops in numbers of subscribers for cable companies, while customers do not gain much from unbundling. In a similar vein, Crawford et al. (2004) also use data from the cable TV industry in the US and find that bundling reduces consumer heterogeneity and that consumer welfare falls while cable companies increase their revenues; ultimately, the total welfare effect is positive.

Finally, the *Special Eurobarometer,* published by the European Commission, contains a large source of consumer data on communications services and consumer satisfaction which could be used for future empirical research. This survey data might be used to explore European consumers' experiences when switching provider, satisfaction with the operator, and tariff transparency, amongst others. Indeed, this survey data has already been used to analyse substitution patterns between fixed and mobile technologies (Grzybowski, 2012).

References[109]

Adams, W. and Yellen, J., 1976. "Commodity bundling and the burden of monopoly", *Quarterly Journal of Economics*, 90, 475-98.

Alabau, A. and Guijarro, L., 2011. "The Electronic Communications Policy of the European Union", Universitat Politécnica de València.

Amichai-Hamburger, Y., and Hayat, Z., 2013. "Personality and the internet". In Y. Amichai-Hamburger (Ed.), The social net: Understanding our online behavior, 1–20. New York: *Oxford University Press*.

Andrés, L., Cuberes, D., Diouf, M., and Serebrisky, T., 2010. "The diffusion of the Internet: A cross-country analysis", *Telecommunications Policy,* 34, 323-340.

Armstrong, M., 2002. "The theory of access pricing and interconnection", *Handbook of Telecommunications Economics*, Vol. I, Elsevier: Amsterdam, 297-384.

Aron D.J. and Burnstein, D., 2003. "Broadband adoption in the United States: an empirical analysis", Shampine, A.L. (Ed.), Down to the Wire: Studies in the Diffusion and Regulation of Telecommunications Technologies, *Nova Science Publishers*, Haupaugge, NY, 119-38.

Bacache, M., Bourreaum M., and Gaudin, G., 2014. "Dynamic Entry and Investment in New Infrastructures: Empirical Evidence from the Fixed Broadband Industry", *Review of Industrial Organisations, forthcoming*, 44 (1), 179-209.

Bekkers, R., 2001. "Mobile telecommunications standards: GSM, UMTS, TETRA and ERMES", Artech House, Boston.

Bel, G, Calzada, J., and Fageda, X., 2006. "Liberalización y Competencia en España: ¿dónde estamos?", *Información Comercial Española*, Vol. 829, 123-144.

Benhabib, J, and Spiegel, M., 2005. "Chapter 13 Human Capital and Technology Diffusion", *Handbook of Economic Growth,* Volume 1, Part A, 2005, 935–966.

[109] Full list of references

Bohlin E., Gruber, H., and Koutroumpis, P., 2010. "Diffusion of new technology generations in mobile communications", *Information Economics and Policy,* 22(1), 51-60.

Bouckaert, J., Van Dijk, T., and Verboven, F., 2010. "Access regulation, competition, and broadband penetration: An international study", *Telecommunications Policy*, 34, 661-671.

Bourreau, M. and Dögan, P., 2006. "Build or Buy Strategies in the Local Loop", *American Economic Review, Papers and Proceedings*, 96 (2), 72-76.

Bourreau, M., Dögan, P., and Manant, M., 2010. "A critical review of the ladder of investment approach", *Telecommunications Policy*, 34 (11), 683-696.

Briglauer, W., Ecker. G., and Gugler, K., 2013. "The impact of infrastructure and service-based competition on the development of next generation access networks: recent evidence from the European member states", *Information Economics and Policy*, 25, 142-153.

Byzalov, D., 2010. "Unbundling Cable Television: An Empirical Investigation," mimeo.

Cabral, L. and Salant, D., 2013. "Evolving technologies and standards regulation", *International Journal of Industrial Organisations.*

Calzada, J. and Costas, A., 2014. "La liberalización de las telecomunicaciones en España: Objetivos europeos versus intereses nacionales", *Revista de Historia Industrial,* forthcoming.

Calzada, J. and Estruch, A., 2011. "Telefonía móvil en España: regulación y resultados", *Cuadernos Económicos de ICE*, 81, 39-71.

Calzada, J. and Estruch, A., 2013. "Comunicaciones Móviles en la Unión Europea: tecnología, políticas y mercado", *Papeles de Economía Española*, N.º 136.

Calzada, J. and Martínez-Santos, F., 2014a. "Broadband prices in the European Union: Competition and commercial strategies", *Information Economics and Policy*, 7, 24–38.

Calzada, J. and Martínez-Santos, F., 2014b. "Competencia en el Mercado de banda ancha móvil en España", *Cuadernos Económicos del ICE*, 88, 97-129.

Calzada, J. and Trillas, F., 2006. "Los precios de precios de interconexión en las telecomunicaciones: de la teoría a la práctica", *Hacienda Pública Española*, Vol. 173, 2, 85-125.

Cambini, C. and Jiang, Y., 2009. "Broadband Investment and Regulation: A literature Review," *Telecommunications Policy*, 33 (10-11), 559-574.

Carlton, D., 2008. "Should Price Squeeze be a Recognized Form of Anticompetitive Conduct?", *Journal of Competition Law and Economics*, 4 (2), 271-278.

Cava, I. and Alabau A., 2006. "Broadband policy assessment: a cross national empirical analysis", *Telecommunications Policy*, 30, 445-463.

Cave, M., 2006. "Encouraging infrastructure competition via the ladder of investment", *Telecommunications Policy,* 30, 223–237.

Cave, M., 2010. "Snakes and ladders: Unbundling in a next generation world", *Telecommunications Policy*, 34, 80–85.

Cave, M. and Prosperetti, L., 2001. "European Communications Networks", *Oxford Review of Economic Policy***,** no 3, 2001.

Cave, M. and Vogelsang, I., 2003. "How access pricing and entry interact", *Telecommunications Policy* 27, 717-727.

Cisco, 2015. "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014–2019".

CMT, 2013a. Informe Económico Sectorial 2012. Comisión del Mercado de las Telecomunicaciones.

CMT, 2013b. "Estrategias de venta de terminales y precio de los servicios móviles", Nota ocasional 7.

CNMC, 2014a. "Efecto arrastre entre las demandas de servicios fijos y de servicios móviles tras la eclosión en España de los paquetes convergentes de servicios fijos y móviles", Documento de Trabajo número 2, Abril 2014.

CNMC, 2014b. "Cambios de operadores de los servicios de comunicaciones electrónicas en el sector residencial en 2013", Documento de Trabajo nº 3, Julio 2014.

CNMC, 2014c. "Informe de seguimiento de las ofertas comerciales de servicios de comunicaciones móviles entre 2012 y 2013", Documento de Trabajo nº 12, Julio 2014.

CNMC, 2014d. "Informe Económico de las Telecomunicaciones y del Sector Audiovisual 2014", Comisión Nacional de los Mercados y de la Competencia.

Corrocher, N. and Zirulia, L., 2010. "Demand and innovation in services: The case of mobile communications", *Research Policy*, Elsevier, Vol. 39(7), 945-955.

Crandall, R., Ingraham, T., and Singer, H.J., 2004. "Do Unbundling Policies Discourage CLEC Facilities-Based Investment", *The B.E. Journals in Economic Analysis and Policy*, 4(1).

Crandall, R., Lehr, W., and Litan, R., 2007. "The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data", *Issues in Economic Policy*, The Brookings Institution, No. 6, July.

Crandall, R., and Sidak, J.G., 2007. "Is Mandatory Unbundling the Key to Increasing Broadband Penetration in Mexico? A Survey of International Evidence".

Crandall, R., Sidak, J.G. and Singer, H.J., 2002. "The empirical case against the regulation of broadband access", *Berkeley Technology Law Journal*, Vol. 17 No. 3, 953-87.

Crawford, G. and Yurukoglu, A., 2012. "The Welfare Effects of Bundling in Multichannel Television Markets", *American Economic Review*, 102(2), 643-85.

Czernich, N., Falck, O., Kretschmer, T. and Woessmann, L., 2011. "Broadband Infrastructure and Economic Growth", *The Economic Journal*, 121 (May), 505-532.

Denni, M. and Gruber, H., 2005. "The Diffusion of Broadband Telecommunications: The Role of Competition" Italian Competition Authority; University of Rome III - Department of Economics, September 2005, Working Paper n° 60, 2006.

Distaso, W., Lupi, P. and Manenti, G., 2006. "Platform Competition and Broadband Uptake: Theory and Empirical Evidence", *Information Economics and Policy*, 18 (1), 87-106.

Divya, Kumar, A., Liu., Y., and Sengupta, J., 2010. "Evolution of Mobile Wireless Communication Networks: 1G to 4G", *International J. of Elect. and Comm*. Tech 1 (1), 68-72.

Economides, N. and Hermalin, B.E., 2015. "The Strategic Use of Download Limits by a Monopoly Platform", forthcoming in *Rand Journal of Economics*, 46, 2, 297-327.

European Commission, 2002. Directive 2002/21/EC of the European Parliament and of the Council.

European Commission, 2003. Commission Recommendation 2003/311/EC.

European Commission, 2007. Commission Recommendation of 17 December 2007. Official Journal L 344 of 28.12.2007.

European Commission, 2009a. "15th Progress Report on the Single European Electronic Communications Market – 2009".

European Commission, 2009b. Regulation (EC) No 1211/2009.

European Commission, 2011. "Broadband Internet Access Costs (BIAC)". Final Report, Information Society and Media Directorate-General.Van Dijk – Management Consulting.

European Commission, 2012a. "Digital Agenda for Europe, Scoreboard 2012". Directorate-General for Communication Networks, Content and Technology (DG-CONNECT), Brussels.

European Commission, 2012b. "Broadband Internet Access Costs (BIAC)". Final Report, Information Society and Media Directorate-General.Van Dijk – Management Consulting.

European Commission, 2012c. E-communications Households Survey. Report. Special Eurobarometer 381. Directorate-General for Information Society and Media, Brussels.

European Commission, 2013a. "The mobile use of the Internet by individuals and enterprises". *Digital Agenda Scoreboard 2013*, Chapter 4, June 2013.

European Commission, 2013b. Broadband Internet Access Costs (BIAC). Final Report, Information Society and Media Directorate-General. Van Dijk – Management Consulting.

European Commission, 2014. E-Communications and Telecoms Single Market Household Survey, *Special Eurobarometer*, No. 414, Brussels.

Evans, D. and Salinger, M., 2005. "Why do firms bundle and tie? Evidence from competitive markets and implications for tying law", *Yale Journal on Regulation*, 22, 37-89.

FCC, 2015. "Fourth International Broadband Data Report", Federal Communications Commission, Washington.

Fornefeld, M., Delaunay, G., Elixmann, D., 2010. "The Impact of Broadband on Growth and Productivity", A study on behalf of the European Commission. Düsseldorf: MICUS.

Gabaix, X. and Laibson, D., 2006. "Shrouded attributes, consumers myopia, and information suppression in competitive markets", *Quarterly Journal of Economics*, 121 (2), 505-540.

Galperin, H., 2012. "Prices and quality of broadband in Latin America: Benchmarking and trends", *Economics of Networks eJournal* 4(64).

García-Mariñoso, B, Martinez-Giralt, X. and Olivella, P., 2008. "Bundling in Telecommunications", UFAE and IAE Working Papers 762.08, Unitat de Fonaments de l'Anàlisi Econòmica (UAB) and Institut d'Anàlisi Econòmica (CSIC).

Gaudin, G., 2012. "Price Squeeze and Monopoly Maintenance in Regulated Industries, mimeo.

Genakos, C. and Valletti, T., 2014. "Evaluating a decade of mobile termination rate regulation", mimeo.

Gillett, S., Lehr, W., and Osorio, C., and Sirbu, M. A., 2006. "Measuring Broadband's Economic Impact", Technical Report 99-07-13829, National Technical Assistance, Training, Research, and Evaluation Project.

Grajek, M., and Röller, L-H., 2012. "Regulation and investment in network industries: Evidence from European telecoms", *Journal of Law and Economics*, 55 (1): 189-216.

Greenstein, S. and McDevitt, R., 2011a. "The Broadband Bonus: Estimating broadband Internet's economic value", *Telecommunications Policy*, 35 (7), 617-632.

Greenstein, S. and McDevitt, R., 2011b. "Evidence of a modest price decline in US broadband services", *Information, Economics and Policy*, 23 (2), 200-211.

Griliches, Z., 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change" *Econometrica* Vol. 25 (October).

Gruber, H., 2007. "3G mobile telecommunications licenses in Europe: a critical review", *Info*, Vol. 9, n.6, 2007, 35-44.

Gruber, H., 2008. "The Economics of Mobile Communications", Cambridge, *Cambridge University Press.*

Gruber, H., and Koutroumpis, P., 2013. "Competition enhancing regulation and diffusion of innovation: the case of broadband networks", *Journal of Regulatory Economics*, 43: 168-195.

Gruber, H. and Verboven, F., 2001. "The evolution of markets under entry and standards regulation - the case of global mobile telecommunications", *International Journal of Industrial Organisations*, Elsevier, Vol. 19(7), 1189-1212, July.

Gruber, H. and Valletti, T., 2003. "Mobile telecommunications and regulatory frameworks", in Emerging telecommunications networks: *the international handbook of telecommunications economics*, volume II, Editor(s): Madden, Cheltenham, Edward Elgar.

Grzybowski, L., 2005. "Regulation of mobile telephony across the European Union: an empirical analysis", Journal of Regulatory Economics, 28 (1): 47-67.

Grzybowski, L., 2008. "The impact of regulation on the retail prices in fixed-line telephony across the European Union", Telecommunications Policy, 32 (2): 131-144.

Grzybowski, L., 2012. "Fixed-to-Mobile Substitution in the European Union, mimeo.

Grzybowski, L. and Dauvin, M., 2014. "Estimating broadband diffusion in the EU using NUTS1 regional data", *Telecommunications Policy*, 38(1), 96-104.

Grzybowski, L. and Liang, J., 2014. "Estimating demand for quadruple-pay tariffs: The impact on consumer surplus", mimeo.

Halvorsen, R. and Palmquist, R., 1980. "The Interpretation of Dummy Variables in Semilogarithmic Equations", *The American Economic Review*, Vol. 70, No. 3, 474-475.

Haucap, J, Heimeshoff, U., and Lange, M., 2014. "The Impact of Tariff Diversity on Broadband Diffusion – An Empirical Analysis", Düsseldorf Institute for Competition Economics, Discussion Paper 156.

Hausman, J. and Sidak, G., 2005. "Did mandatory unbundling achieve its purpose? Empirical evidence from five countries", *Journal of Competition Law and Economics*, 1, 173-245.

Hazlett, T. and Bazelon, C., 2005. "Regulated Unbundling of Telecommunications Networks: A Spetting Stone to Facilities-Based Competition", mimeo.

Hillebrand, F., 2013. "The Creation of Standards for Global Mobile Communication: GSM and UMTS Standardization from 1982 to 2000", *IEEE Wireless Communications*, 24-33.

Hoernig, S., 2001. "Collusion and confusion?", mimeo.

Höffler, F., 2007. "Cost and benefits from infrastructure competition. Estimating welfare effects from broadband access competition", *Telecommunications Policy, 31*(6-7), 401-418.

Hovenkamp, H., 2008a. "The Antitrust Enterprise, Principle and Execution", *Harvard University Press*, United States.

Hovenkamp, H., 2008b. "Unilateral refusals to deal, vertical integration, and the essential facility doctrine (July 1, 2008)", U. Iowa legal studies research paper No. 08-31.

Inderst, R. and Peitz, M., 2012. "Informing consumers about their own preferences", *International Journal of Industrial Organisations*, Elsevier, Vol. 30(5), 417-428.

ITU, 1999. "World Telecommunication Development Report, Mobile Cellular".

ITU, 2003a. "Collection of the basic texts of the International Telecommunication Union adopted by the plenipotentiary conference", edition 2003.

ITU, 2014. “Measuring the Information Society Report 2014”.

ITU & UNESCO, 2014. “Broadband Commission for Digital Development”.

Katz, R. and Suter, S., 2009. “Estimating the economic impact of the broadband stimulus plan”, Columbia Institute for Tele-Information Working Paper.

Kaugant, C. and Bohlin, E., 2014. “Impact of mobile termination rates on retail prices: the implications for regulators”, *Info*, Vol. 16 (2), 80-93.

Kehoe, J., Kim, J., 2009. “Sudden Stops, Sectoral Reallocations, and the Real Exchange Rate”, *Journal of Development Economics*, 2009, 89(2), 235-249.

Kiiski, A., 2006. “Impacts of MVNOs on Mobile Data Service Market”. 17th European Regional ITS Conference.

Kimiloglu, H., Ozturan, M., Kutlu, B., 2011. "Market Analysis for Mobile Virtual Network Operators (MVNOs): The Case of Turkey", *International Journal of Business and Management*, Vol: 6, No. 6, 39-54.

Kleinrock, L., 2005. "A Vision for the Internet," *ST Journal for Research*, Vol. 2, no. 1, 4–5.

Koski, H. and Kretschmer, T., 2004. “Entry, Standards and Competition: firm strategies in the diffusion of mobile telephony, *Review of Industrial Organisations*, 26, 89-113.

Koutroumpis, P., 2009. “The economic impact of broadband on growth: A simultaneous approach”, *Telecommunications Policy,* 2009, Vol. 33, issue 9, 471-485.

Kraut, R., Mukhopadhyay, T., Szczypula, S., Kiesler, S., and Scherlis, W., 1998. “Communication and information: Alternative uses of the Internet in households”, In Proceedings of the CHI 98, 368-383. New York: ACM.

Laffont, J. and Tirole, J., 2000. "*Competition in Telecommunications"*, Cambridge, Mass, *The MIT Press*.

Lee, S., Marcu, M. and Lee, S., 2011. "An Empirical analysis of fixed and mobile broadband diffusion", *Information Economics and Policy*, 23, 227-233.

Leider, S. and Sahin, O., 2015. Contracts, biases and consumption of access services, mimeo.

Leiner, B.M., Cerf, V.G., Clark, D.D., Kahn, R.E., Kleinrock, L., Lynch, D.C., Postel, J., Roberts L.G., Wolff S., 2003. "A Brief History of the Internet", *Internet Society*.

Liikanen, J., Stoneman, P. and Toivanen, O., 2004. "Intergenerational effects in the difussion of new technology: the case of mobile phone", *International Journal of Industrial Organisations*, 22 (8-9), 1137-1154.

Lyons, D., 2013. "Internet Policy's Next Frontier: Data Caps, Tiered Service Plans, and Usage Broadband Pricing", *Federal Communications Law Journal*, 66, 1, 1-44.

McAfee, R.P., McMillan, J. and Whinston, M.D., 1989. "Multiproduct Monopoly, Commodity Bundling, and Correlation of Values", *The Quarterly Journal of Economics*, MIT Press, Vol. 104(2), 71-83, May.

McDevitt, Ryan C., 2011. "Names and Reputations: An Empirical Analysis", *American Economic Journal: Microeconomics*, 3 (3), 193-209.

Nakamura, A., 2015. "Mobile and fixed broadband access services substitution in Japan considering new broadband features", *Telecommunications Policy,* Volume 39, Issue 2, 93-158.

Nalebuff, B., 2004. "Bundling as an entry barrier", *Quarterly Journal of Economics*, 119, 159-87.

Nardotto, M., Valletti, T. and Verboven, F., 2014. "Unbundling the Incumbent: Evidence from UK broadband," CEIS Research Paper 331, Tor Vergata University, CEIS.

Nelson R. and Phelps E., 1996. "Investment in Humans, Technological diffusion and Economic Growth", *American Economic Review*. May 56 (2).

OECD, 2008. "Broadband Growth and Policies in OECD Countries". OECD Ministerial Meeting on the Future of the Internet Economy.

OCDE, 2012. "OCDE Communications Outlook 2011. *OCDE Publishing*.

OCDE, 2014a. "OCDE Communications Outlook 2013". *OCDE Publishing*.

OECD, 2014b. "The Development of Fixed Broadband Networks", OECD Digital Economy Papers, No. 239, *OECD Publishing*. http://dx.doi.org/10.1787/5jz2m5mlb1q2-en.

OECD, 2015. "Broadband subscriptions per 100 inhabitants in OECD countries", Last updated February 2015. OECD Broadband Portal.

OFCOM, 2014. "The European Broadband Scorecard, Research Document", 12 March 2014.

OFCOM, 2014b. "Measuring mobile broadband performance in the UK", Research document, November.

Papacharissi, Z., and Zaks, A., 2006. "Is Broadband the Future? An Analysis of Broadband Diffusion and Potential and diffusion", *Telecommunications Policy,* 30, 64-75.

Pereira, P. and Ribeiro, T., 2010. "The impact on broadband access to the Internet of the dual ownership of telephone and cable networks", *International Journal of Industrial Organisations,* 29, 283–293.

Prat, A. and Valleti, T., 2003. "Spectrum Auctions Versus Beauty Contests: Costs and Benefits", en Mario Baldassarri y Luca Lambertini (eds.), Antitrust, *Regulation and Competition*, Palgrave Macmillan, London.

Prince, J. and Greenstein, S., 2014. "Does service Bundling reduce churn", *Journal of Economics and Management Strategy*, forthcoming.

Rajani, M. K., & Chandio, M. S., 2004. "Use of Internet and its effects on our Society", Proceedings of the National Conference on Emerging Technologies (NCET), December 18-19, 2004 157-161.

Renda, A., 2010. "Competition–regulation interface in telecommunications: What's left of the essential facility doctrine", *Telecommunications Policy* 34 (1), 23-35.

Rickford, J., 1998. "Change, politics and determinist economics in Europe", *Telecommunications Policy,* Vol. 22, 471-82.

Roller, LH., and Waverman, L., 2001. "Telecommunications Infrastructure and Economic Development: A Simultaneous Approach". *American Economic Review*, 91(4): 909-923.

Sidak, J.G., 2008. "Abolishing the Price Squeeze as a Theory of Antitrust Liability", *Journal of Competitive Law and Economics*, 4 (2), 279-309.

Sinkinson, M., 2014. "Pricing and Entry Incentives with Exclusive Contracts: Evidence from Smartphones", mimeo.

Srinuan, P., Bohlin, E., and Madden, G., 2012. "The determinants of mobile subscriber retention in Sweden". *Applied Economics Letters,* 19(5), 453 – 457.

Srinuan, C., Srinuan, P., and Bohlin, E., 2012. "An analysis of mobile Internet access in Thailand: Implications for bridging the digital divide". *Telematics and Informatics 29(3),* 254-262.

Srinuan, C.,Srinuan, P., and Bohlin, E., 2013. "Pricing strategies and innovations in the Thai mobile communications market", *Info*, 15 (1), 61 – 77.

Srinuan, C., Srinuan, P., and Bohlin, E., 2012. "Fixed and mobile broadband substitution in Sweden", *Telecommunications Policy, 36(3),* 237-251.

Stigler, George J., 1971. "The theory of economic regulation", *Bell Journal of*

Economics and Management Science, Vol. 2, Issue 1 (spring, 1971): 3-21.

Sung, N. and Kwon, M., 2011. "An empirical analysis of the state of competition in OECD mobile wireless markets", 22nd European Regional Conference of the International Telecommunications Society (ITS2011), Budapest.

Teppayayon, O. and Bohin, E., 2010. "Functional separation in Swedish broadband market: Next step of improving competition", *Telecommunications Policy,* 34, 375-383.

Tirole, J., 1988. "The Theory of Industrial Organisations", Cambridge, MA: *The MIT Press.*

Trinh, T.A., Abos, I., Sallai, G., 2012. "Net Neutrality under Usage-Based Pricing: a Game-Theoretic Analysis with User Loyalty", 23rd European Regional International Telecommunication Society Conference. Vienna, Austria, July 1-4, 2012.

Valletti, T., 2003. "Input price discrimination with downstream Cournot competitors", *International Journal of Industrial Organisations*, Elsevier, Vol. 21(7), 969-988.

Vogelsang, I., 2003. "Price Regulation of access to telecommunications networks", *Journal of Economic Literature*, 41 (3).

Vogelsang, I., 2010. "The Relationship between mobile and fixed-line communications: a survey", *Information Economics and Policy*, 22(1): 4-17.

Wallsten, S., 2006. "Broadband and Unbundling Regulations in OECD Countries", AEI-Brookings Joint Center for Regulatory Studies Working Paper.

Wallsten, S. and Hausladen, S., 2009. "Net Neutrality, Unbundling, and their Effects on International Investment in Next-Generation Networks", *Review of Network Economics* Vol.8, Issue 1 – March 2009.

Wallsten, S. and Riso J.L., 2010a. “Residential and Business Broadband Prices: Part 1: An Empirical Analysis of Metering and Other Price Determinants”, Technology Policy Institute.

Wallsten, S. and Riso, J.L., 2010b. “Residential and Business Broadband Prices: Part 2: International comparisons”, Technology Policy Institute.

Wallsten, C. and Mallahan, 2010. “Residential broadband competition in the United States”, SSRN eLibrary.

Waverman, L., Leschi, M., Reillier, B., and Dasgupta, K., 2007. “Access regulation and Infrastructure Investment in the Telecommunications Sector: An empirical Investigation”, mimeo.

Willig, R., 2006. “Investment is appropriately stimulated by TELRIC”. Princeton University.

Wilson, R., 1993, “Non linear pricing”. New York: *Oxford University Press*.

Zhu, T., Liu, H., and Chintagunta, P., 2011. “Wireless Carriers’ Exclusive Handset Arrangements: An Empirical Look at the iPhone”, Working Papers 11-35, NET Institute.