

Platform Competition and Broadband Adoption in Europe: Theory and Empirical Evidence from the European Union*

Walter Distaso[†] Paolo Lupi[‡] Fabio M. Manenti[§]

March 2004

Abstract

Broadband access provides users with high speed, always-on connectivity to the Internet. Due to its superiority, broadband is seen as the way for consumers and firms to exploit the great potentials of new applications. This has generated a policy debate on how to stimulate adoption of broadband technology. One of the most disputed issues is about competition policies: these may be intended to promote competition in the Digital Subscriber Line (DSL) segment of the market (intra-platform competition), or to stimulate entry into the market for alternative platforms such as cable access or fiber optics (inter-platform competition). Using a model of oligopoly competition between differentiated products, our paper explicitly studies the effect of inter and intra platform competition on the diffusion of broadband access. The implications of the model are then tested using data from 14 European Countries. The econometric evidence confirms the results of the theoretical model and indicates that while inter-platform competition drives broadband adoption, competition in the market for DSL services does not play a significant role.

Keywords: Broadband, inter-platform and intra-platform competition, local loop unbundling.

JEL classification: L86, L96.

*Distaso gratefully acknowledges financial support from the ESRC, grant code R000230006.

[†]Department of Economics, University of Exeter, Exeter EX4 4PU, UK, e-mail: w.distaso@ex.ac.uk.

[‡]Servizio Analisi di Mercato e Concorrenza, Autorità per le garanzie nelle comunicazioni, Centro Direzionale, Isola B5 - 80143 Napoli (Italy), e-mail: p.lupi@agcom.it. The views and opinions expressed herein are solely those of the author and do not necessarily reflect those of the Autorità per le garanzie nelle comunicazioni.

[§]Dipartimento di Scienze Economiche "M. Fanno", Università di Padova, Via del Santo 33, 35123 PADOVA (Italy), Tel. (39) 49 8274238, email: fabio.manenti@unipd.it.

1 Introduction

The increased importance of information and communication technologies (ICT) as *the* major “General Purpose Technology” underlying the knowledge economy and, consequently, the rapid increase in investment in ICT, are considered by many as the key factor of the acceleration of productivity growth experienced by the United States during the last decade. Probably, of the many technologies that fall under the ICT umbrella, Internet is the one that has had the biggest impact in terms of cost savings and profitability increases in business.¹

It is easy, then, to understand why Internet policy is playing a predominant role in many governments’ agendas; the European Council, recognising that the contribution of ICT to growth in Europe was too low and that much more could be expected, set in March 2000 the so-called “Lisbon strategy” aimed at making the European Union the most competitive and dynamic knowledge-based economy by 2010. To achieve this goal the European Commission and Council draw and endorsed the *e*Europe 2002 action plan, focused on extending Internet connectivity and on reducing access prices.

In order to generate growth, connectivity needs to be translated into economic activities; hence the strategic importance of accessing the Internet at high speed does not derive only from its capacity to accelerate the contribution of ICT to economic growth, but also from its capacity of delivering large benefits to consumers in terms of new or improved products and services.² The European Council consequently endorsed the *e*Europe 2005 action plan. The plan is directed at stimulating services, applications and content capable of creating new markets and reducing costs, thanks to two new technological developments (deemed able to further expanding the potentialities of the Net): multi-platform access/convergence and broadband. For this reason, the main objective of the 2005 action plan is to get a widespread availability of broadband access at competitive prices in Europe by 2005.

¹Varian et al. (2002) estimated that the adoption of Internet business solutions had yielded to US organisations, from the first year of implementation through 2001, cumulative cost savings of \$155.2 billion and increased revenues of \$444 billion.

²Crandall et al. (2002), for example, report that in US consumer benefits from universal broadband deployment, that is to say 94% of US households, which is the current level of telephone service, could easily be \$300 billion a year and that 50% deployment would result in benefits of around \$100 billion annually (benefits increase nonlinearly due to network effects).

Initiatives to promote the deployment and adoption of broadband services are not confined to the European Union and to the USA, though they (together with Korea) acted as first movers. In fact, in the last couple of years an increasing number of governments, mainly in the OECD area, have studied and adopted initiatives to support the diffusion and availability of broadband access services within public administrations, schools, the private sector and, ultimately, residential users.

Broadband diffusion policies are being put in place not only in consideration of the economic and social relevance of providing business and residential users with high speed access technologies, but also because there is a widespread concern that, in spite of contrary evidence,³ broadband diffusion is taking place too slowly, or at least more slowly than originally predicted.

Public initiatives implemented by central and local governments to stimulate broadband adoption can be classified in two broad categories: i) policies aimed at assisting the build up of broadband networks and ii) policies aimed at enhancing competition through telecom markets openness and access to infrastructures.

All policies directed at financially assisting telecommunication providers,⁴ at establishing public-private partnerships (i.e. through public sector demand aggregation) and at building government-owned networks, fall within the first category. On the other hand, pro-competitive policies put into place by regulatory authorities such as compulsory unbundling of the local loop, shared access, wholesaling and technological neutrality aimed at stimulating market-entry and at providing incentives to reduce prices, fall into the second category.

There is a general consensus on the idea that competition is the main driver of the adoption of broadband technologies (see e.g. OECD, 2001, 2002, 2003a). In these official documents particularly debated is the issue of the different available options to induce competition in the market for broadband access. In particular, whether competition should be introduced and promoted between different technological platforms able to offer broadband access (inter-platform competition); or

³Empirical evidence shows that broadband take-up is actually happening quite at a fast pace relative to the adoption of similar communication technologies. For example, OECD (2003b) shows that at the end of 2003, seven years after the introduction of broadband access services, the number of broadband subscribers across OECD countries exceeded by a considerable amount that of subscribers to mobile phone services, to analogic and Individual Subscriber Digital Number (ISDN) dial-up access services at the same stage of market development.

⁴Financial support may be provided either directly (through tax incentives, low interest loans and subsidies) or indirectly (through financial support to municipalities or end users).

within the same platform (intra-platform competition).⁵

The aim of this paper is to analyze the role of competition in promoting broadband adoption. Using a model of oligopoly competition between differentiated products, our paper explicitly studies the distinct effects of inter and intra platform competition on the diffusion of broadband access. The empirical evidence, using data available for 14 European Countries, supports the theoretical predictions of the models and establishes inter-platform competition as the main driver for broadband adoption, while competition within the DSL segment of the market seems to play a less significant role.

The remainder of this paper is structured as follows: in Section 2 we describe the most common broadband technologies, while Section 3 briefly reviews the literature on broadband diffusion. The theoretical model of oligopoly competition is introduced in Section 4, and its main implications are empirically tested in Section 5. Finally, in Section 6 we draw some concluding remarks.

2 Broadband technologies

Despite all this interest in promoting broadband access, there is still no agreement on the definition of broadband. In fact, definitions given by governments and international institutions usually vary. For example, the International Telephony Union defines broadband as a technology providing a transmission capacity that is faster than primary rate ISDN (1.5 or 2 Mbps), while OECD defines broadband as a technology providing downstream speed in excess of 256 Kbps (and upstream access speed in excess of 128 Kbps). Other governments and institutions, given the fast pace of technical progress in ICT, prefer not to specify any speed or technical requirement, and their definitions mainly rely on the services that can be provided over broadband. In this paper, given the broad variety of broadband products delivered over different networks available to end users, we adopt a flexible definition. Broadband is identified with any access technology that guarantees the final customers connections (in terms of speed of data transfer) to the net of greater quality than traditional analogic or ISDN modems dial-up technologies. All the technologies briefly described below satisfy our definition.

⁵Given the actual state of the market for broadband access, this form of competition seems to be viable only within the DSL segment of the market.

Digital Subscriber Line (DSL) The most popular broadband technology, it converts the standard telephone line into a high speed digital line by transmitting data at higher frequencies than those used for voice. For this reason DSL technologies allow for simultaneous use of voice telephony and data services. There are various forms of DSL: Asymmetric DSL (ADSL), High Rate DSL (HDSL), Symmetric DSL (SDSL) and Very High Data Rate DSL (VDSL), which are able to provide connection speeds ranging from 256 Kbps to 52 Mbps.

Cable modem A broadband technology that uses access lines for cable television (CATV). Although traditional CATV networks need to be upgraded with a separate voice line to provide interactive communication services like telephony and Internet access, new networks use the same coaxial cable to provide simultaneous transmission of data, television and voice. Connection speeds range from 1 to 10 Mbps.

Fibre to the home (FTTH) A Fibre optic technology similar to standard cable that allows for transmission speeds of up to 10 Gbps. Fiber optic cables are rolled out up to home of the consumer and can carry video, data, voice and interactive video-telephone services.

Satellite A broadband technology that uses satellite TV equipment to carry data. At the moment the majority of services based on satellite technology are one-way (i.e. they only allow for downstream transmission) and need a dial-up connection for the return channel. The downstream speed ranges between 300 Kbps and 2 Mbps. This technology is considered to be particularly effective for servicing rural areas where other technologies are too expensive to be put in place.

Fixed Wireless Access (FWA) A technology, initially deployed as an alternative to the local copper loop, which uses radio links between a base station and a receiving antenna located in the customer's premises. It allows for simultaneous transmission of voice and data and can reach speeds of over 2 Mbps.

Power lines communications (PLC) A broadband technology that relies on the existing electricity distribution network to transmit data at speeds comparable to those offered by DSL. This technology is still in the testing phase of development and, given the ubiquity of the power network (as e.g. satellite), looks particularly promising for deploying broadband in

rural areas.

In addition to these technologies listed above there are a few others belonging to the family of mobile technologies (e.g. third generation, UMTS) and some other defined as “nomadic” (e.g. radio-LANs). Although very promising in terms of connection speed and deployment, they are, like FWA and PLC, still confined to a small number of adopters. It is for this reason that in our empirical analysis we will use data concerning only DSL, cable, fiber and satellite technologies.

3 Review of the literature

Broadband is still at its infancy and there are only few empirical studies available on broadband diffusion. Bauer et al. (2003) presented a cross-national study of broadband uptake in the 30 OECD countries. Due to problems of data availability which restricts the analysis to year 2001, the authors estimate a cross sectional model which does not capture the dynamic evolution of the broadband market. The aim of the authors was to study the main drivers influencing broadband penetration; among the regressors they included the price of broadband, the price of dial-up services and a variable indicating the competitive conditions in the broadband market. Quite surprisingly, all these variables came out to be statistically insignificant.⁶ This result is probably due to the constraint imposed by the limited availability of the data. Like any process of new technology diffusion, broadband adoption is a dynamic process that evolves through time and this crucial feature is not taken into account in the estimated cross-sectional model. Furthermore, the authors do not study the role of the different competitive conditions in the broadband market, which is indeed the main focus of our paper.

An interesting investigation, more closely related to ours⁷, is presented in Aron and Burnstein (2003). These authors estimate the influence of availability, competition and demographics on the adoption of broadband technology in 46 US states. The paper focuses on the effect of inter-platform competition on broadband penetration relative to the effect of simple broadband availability (i.e. when only one platform is available); other variables included in the regressors are the price for unbundled local loop, the number of internet access and the level of education. The authors find

⁶The fully specified model yielded significant parameters only for two variables: population density and a variable called “preparedness”, intended to capture the attitudes of a population towards information technology.

that inter-platform competition, mainly between cable and DSL technologies, has a positive and significant impact on broadband adoption. Again, the model estimated by Aron and Burnstein (2003) is a cross-sectional one and therefore it is a static model; furthermore the authors do not analyse the role of intra-platform competition on broadband uptake, which represents a relevant policy issue currently under scrutiny.

Garcia-Murillo and Gabel (2003) study the stimulating role of unbundling policies and other regulatory activities in local telecommunications. Their study includes 135 countries, with observations restricted to the year 2001. In their paper, the authors do not distinguish between inter and intra-platform competition when trying to estimate the determinants of broadband adoption. Quite surprisingly, Garcia-Murillo and Gabel do not find evidence of a positive role of unbundling policies towards broadband adoption; stronger evidence is found on the role of competition.

A different issue is tackled in Hausman et al. (2001) where the authors focus on the definitions of the boundaries of the broadband market. The aim of the paper is to understand the economic incentives of the providers of broadband access to limit the usage of broadband access and to verify the existence of significant providers' market power. A related and extremely debated issue is then to test the hypothesis that narrowband and broadband access are two separated markets; interestingly, Hausman et al. (2001) show that the price of narrowband dial-up access does not constrain the prices charged for broadband access, thus supporting the hypothesis that markets are separated.

Finally, various papers use population survey data to analyse the influence of demographic characteristics on individual's decisions to adopt broadband; Stanton (2004) and Rappoport et al. (2002) are two of the most recent papers in this emerging literature.

The picture emerging from the reviewed literature seems to be that the determinants of broadband adoption are still quite unknown; in particular there are no empirical studies providing evidence on the impact of different competition policies on the adoption of broadband access technologies in a more dynamic context. In our paper we focus on the role of inter-platform versus intra-platform competition and on the influence of unbundling policies; the analytical results of a model of platform competition are outlined in the next section.

4 A simple model of platform competition

In order to stimulate adoption of broadband technologies, governments have adopted various initiatives usually intended to promote competition in the access market.

As discussed in the previous sections, a common practice to entice competition in the market for broadband access services is to mandate incumbent telecom carriers to unbundle their local loop and to provide interconnection to any Internet Service Provider (ISP) demanding access at a predetermined-regulated price. Since local loop unbundling allows competitive ISPs to provide DSL services resting on existing network infrastructure, it represents the easiest and the most cost effective policy to stimulate entry into the market for broadband-DSL services. Alternatively, governments may promote competition into markets for cable or fiber optics access through investment subsidies or tax savings. In this case, cable and fiber optic providers need to incur in relevant investments to build their new infrastructures and this makes these alternative forms of broadband access of less immediate availability to final customers.

It is often claimed among practitioners and policy makers that broadband adoption can be stimulated more effectively promoting competition between different platforms (inter-platform competition) rather than focusing on the market for DSL services (intra-platform competition). One of the aim of the paper is to look for a theoretically supported empirical evidence to this claim. For this reason we devote this section to develop an extremely stylised model of intra-platform vs. inter-platform competition; the scope of this model is to provide a simple theoretical background for the empirical analysis conducted in the next section.

We proceed by following a standard model of oligopoly competition between differentiated products. For the sake of simplicity, suppose that broadband access is provided only through two technologies, i.e. DSL and cable; furthermore, let us assume that DSL and cable access are provided by n and m firms respectively. Finally, according to the observation that the market for DSL is generally more competitive than the market for alternative technologies, we also assume that that $n > m > 0$.

Since the main product differentiation across Internet providers is in the quality of the access that they guarantee to their customers (i.e. the speed of connection), it is reasonable to assume homogeneity between firms belonging to the same technology and product differentiation across

technologies. Applying a standard approach of product differentiation to this framework,⁷ demand for DSL and cable technologies can be represented respectively as

$$p_d = \alpha - \beta Q - \gamma Y,$$

and

$$p_c = \alpha - \gamma Q - \beta Y,$$

where $Q = \sum_i^n q_i$ and $Y = \sum_j^m y_j$ represent the total amount of DSL and cable access demanded, q_i and y_j denote the amount of access provided respectively by the individual firms i and j , and finally p_d and p_c refer to the respective prices.

Imperfect substitutability across technologies is easily incorporated by assuming that the own price effect dominates, i.e. $\beta > \gamma > 0$: the impact of increasing DSL (resp. cable) access on the price for DSL (resp. cable) is larger than the effect of the same increase in cable (resp. DSL).

On the cost side, each ISP providing DSL services has to pay the incumbent firm for the unbundled local loop. The price of the local loop is usually made of a fixed and a variable part, where this latter depends on the amount of bandwidth purchased. For the sake of simplicity, we do not explicitly include the one-off charge in the model and consider a constant variable and marginal access charge, indicated by c .

A firm providing cable broadband does not need access to the local loop of the telecom network; as it has been already discussed above, although cable providers often lease lines from the incumbent telecom operator, they mainly have to build their own infrastructure to serve the market. Formally, we assume that a cable provider does not have marginal cost but only a fixed cost of entry, indicated with F .⁸

According to these assumptions, individual firms' profits are

$$\pi_d = (p_d - c)q_i, \quad \pi_c = p_c y_j - F,$$

⁷See Shy (1995).

⁸Note that also DSL firms may incur in fixed costs; these costs, that do not play any role in this stylised framework anyway, are usually smaller than those incurred by cable firms since DSL firms do not have the necessity to build their network and can mainly have interconnection with the existing telecom infrastructures. For simplicity we normalise them to zero: F can be interpreted as the difference in fixed costs between DSL and cable firms. As for marginal costs, also cable firms often have to pay the incumbent network for leased lines; for similar reasons as above, these costs are generally lower than those incurred by DSL firms for the unbundled local loop. Therefore we may again interpret c as the difference in marginal costs between DSL and cable firms.

where, as above, the subscript d refers to DSL and c to cable. Each firm sets its quantity in order to maximise profits. Solving the first order conditions,⁹ it is easy to derive the total amount of broadband access $BB = Q + Y$ at the symmetric equilibrium:¹⁰

$$BB(c, n, m) = \frac{n(\alpha\gamma m - \beta(\alpha - c)(1 + m))}{\gamma^2 mn - \beta^2(1 + n)(1 + m)} + \frac{m(\gamma(\alpha - c)n - \alpha\beta(1 + n))}{\gamma^2 mn - \beta^2(1 + n)(1 + m)}. \quad (1)$$

Clearly, total access depends on the price for local loop unbundling, c , and on the degree of competition between firms providing DSL and cable services respectively, here represented by the number of firms in the two markets, n and m .¹¹

In order to reconcile our theoretical predictions with the results of the empirical analysis provided in the next section, it is useful to discuss in details the two concepts of intra and inter-platform competition. In the empirical exercise we measure the degree of intra and inter-platform competition using the Herfindhal index (HHI), which is usually defined as a sum of firms' squared market size. This index takes the value of 1 when the market is entirely controlled by a single firm/platform, and it decreases as concentration reduces.

In this symmetric framework, the HHI for the degree of competition between DSL firms (intra-platform) is perfectly related to the number of DSL firms:¹² as n increases, intra-platform competition also increases and the HHI decreases accordingly.

Conversely, the relationship between the degree of competition between DSL and cable firms, here represented by n and m , and the HHI for the inter-platform competition is a bit more intricate;

⁹The first order conditions are

$$\begin{aligned} \frac{d\pi_d}{dq_i} &= -\beta q_i + \alpha - \beta \left(q_i + \sum_{j \neq i} q_j \right) - \gamma \sum_{i=1}^m y_i - c, \\ \frac{d\pi_d}{dy_i} &= -\beta y_i + \alpha - \gamma \sum_{i=1}^n q_i - \beta \left(y_i + \sum_{j \neq i} y_j \right). \end{aligned}$$

It is immediate to check that second order conditions are satisfied.

¹⁰Obtained by setting $q_i = q$ and $y_i = y$.

¹¹Note that although $n > m$, total cable access, Y , can be larger than total DSL access, Q and this depends on parameters' values. This replicates what has been observed in some countries of our sample such as Austria, Portugal and the UK; see Table 1 below.

¹²The HHI for intra-platform concentration is:

$$\sum_{i=1}^n \left(\frac{q_i}{Q} \right)^2.$$

At the symmetric equilibrium it reduces to $1/n$.

at the symmetric equilibrium, the HHI for the degree of competition across technologies is defined as follows:

$$HHI_{inter}(n, m) = n \left(\frac{q}{BB} \right)^2 + m \left(\frac{y}{BB} \right)^2$$

where q and y represent individual DSL and cable firms' output respectively, and BB is the total broadband access sold at the equilibrium, as from expression (1).

Inter-platform concentration may vary either because n changes or because m changes or because both change. Let us indicate with dn and dm the variations in the number of firms providing DSL and cable respectively; given the symmetry of our equilibrium and provided that $n > m$, the HHI for the degree of competition between platforms may decrease (i.e. technologies become more evenly adopted) when one of the following situations occur:

Scenario 1: n decreases and m increases: $dn < 0$ and $dm > 0$. In this case the total amount of DSL access, Q , decreases and the total amount of cable, Y , increases; since we move from a situation of dominant DSL technology, this implies a decrease in inter-platform concentration.

Scenario 2: both n and m increase but $dm > dn > 0$. In this case both Q and Y may increase but cable market share increases relatively to DSL and concentration again decreases.

Scenario 3: both n and m decrease, but $dn < dm$, that is the number of DSL firms decreases relatively more than cable.

In other words, there is no direct mapping between HHI_{inter} and the variations in the degree of competition in the DSL and in the cable segment of the market.

Finally, note that scenarios 1 and 3 are of little practical relevance, since in the reality we have been observing a growing number of providers, either cable or DSL. Scenario 2 is indeed the one really observed: in almost the entire sample of countries considered for the empirical exercise the number of firms has been increasing irrespectively on the kind of access provided. For this reason, in the remaining of this section we will always refer to Scenario 2.

We are now ready to derive some testable remarks; remark 1 and 2 highlight the role of local loop unbundling on broadband diffusion while remark 3 focuses on the distinct effects of intra and inter-platform competition.¹³

¹³All proofs are in the mathematical appendix.

Remark 1. The lower the price for local loop unbundling (LLU), the higher the broadband adoption:

$$\frac{dBB}{dc} < 0.$$

Remark 2. Consider Scenario 2: a reduction in the price of LLU may be more effective in promoting broadband the lower inter-platform concentration; formally

$$\frac{d\left(\frac{dBB}{dc}\right)}{dHHI_{inter}} > 0, \quad \text{when} \quad \frac{dn}{dm} > \frac{n\gamma(\beta + n(\beta - \gamma))}{\beta(m+1)(\beta + m(\beta - \gamma))}.$$

Notice that c represents a cost for DSL firms; therefore the intuition for Remark 1 is obvious: a lower price of LLU enhances the competitive position of DSL firms; since DSL is the dominant technology, this translates into more broadband access sold in the retail market. According to Remark 2, the stimulating effect of a reduction of the price of LLU on broadband adoption may be more pronounced the higher the degree of inter-platform competition. Note that Remark 2 simply states a necessary (but not sufficient) condition for this to happen; in particular, the condition given in Remark 2, under which the impact on broadband adoption of a lower LLU price may be stronger the more competitive the market, is more likely to be met when the two platforms provide sufficiently differentiated access (the difference $\beta - \gamma$ must be large enough) and/or the number of firms n and m in the two segments do not differ too much.

The message sent by Remark 2 is that a policy based on lowering the price of LLU may be reinforced by pro-competitive measures aimed at stimulating competition between different platforms; this result, that sounds counterintuitive, contrasts with what has often been claimed and shows that under certain circumstances these two policies may actually go in the same direction.

Remark 3. Let Scenario 2 hold. Then both intra-platform and inter-platform competition stimulate broadband adoption, but inter-platform competition is generally more effective than intra-platform competition. Formally

$$\frac{dBB}{dHHI_{inter}} < 0, \quad \frac{dBB}{dHHI_{intra}} < 0$$

and

$$\left. \frac{dBB}{dHHI_{intra}} \right|_{c \rightarrow \bar{c}} = 0,$$

where $\bar{c} = \frac{\alpha(\beta + m(\beta - \gamma))}{(m+1)\beta}$.

This result has a clear explanation. Competition both intra and inter-platform stimulate adoption through low prices; nevertheless the impact of intraDSL competition is smoothed by the fact that DSL firms have to pay a price for the local loop: when c is high enough, the positive effect of increased competition among providers of DSL services is dissipated by the disadvantage that these firms face in competing with cable firms.

The results and implications of this theoretical model are tested in the next section, through an empirical analysis based on data over a sample of EU countries.

5 Evidence from an empirical analysis

5.1 The data

Our panel dataset was built by joining data and information coming from different sources concerning the three broad categories of users and infrastructures, prices and regulatory policies. In particular, all data related to the number of analogic and ISDN digital lines (as well as the number of DSL, CATV, broadband upgraded CATV, fiber optic and satellite lines) were taken from Telecom Markets, a telecom industry newsletter providing quarterly data and statistics detailing fixed-line subscribers and infrastructures broken down by technology. All data on input prices such as unbundling of the local loop, shared access, leased lines one-off and recurring fees, as well as data on the regulation of the rights of way, were taken from the annual reports on the implementation of the telecommunications regulatory package of the European Commission.¹⁴ In many cases data from reports of the European Commission were complemented with data taken from *The Cross Country Analysis*, a bi-monthly publication which provides an overview of the telecom's regulatory situation of Western European Countries.

The dataset contains information on the following countries: Austria, Belgium, Denmark, France, Finland, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom, that is to say all EU-15 countries except Greece, for which we had difficulties in obtaining reliable data on the number of broadband lines. Each country was observed in quarterly time intervals during the period going from the fourth quarter of year 2000 — there are no reliable

¹⁴In particular, data for year 2000 were taken from the sixth report, data for year 2001 from the seventh report and so on until year 2003.

sources of data on the diffusion of broadband access lines before that date — until the second quarter of 2003, that is the latest period for which data were available at the moment of writing this paper. Our data are available over 11 time periods and 14 countries, but the panel is unbalanced,¹⁵ resulting in a total of 112 observations.

In order to investigate empirically the relationships between broadband uptake and inter/intra platform competition we have built the variables listed below.

PENBB A measure of broadband penetration. Unlike traditional measures of penetration, which weight the number of units of a certain product sold in the market by total population or number of households, our weights the number of broadband lines by the total number of access lines. The number of lines is obtained by dividing the sum of DSL, Cable TV, fiber optic and satellite lines by the the sum of twisted pair copper lines, cable TV lines, fiber optic and satellite lines. Thus, *strictu sensu*, our indicator measures the number of all possible access lines that have been upgraded to transmit high-speed data.

INTRA An index measuring the level of market concentration/competition within the DSL technological platform. As already mentioned in Section 4 our measure of competition (or the lack thereof) is the standard Herfindhal index.

INTER An index measuring the level of market competition/concentration across different technological platforms. As already mentioned, we measure competition (or the lack thereof) across different technological platforms using a particular version of the Herfindhal index which is not computed over firms' market shares, but over technologies' market shares.

ROW1 A dichotomous variable taking the value of 1 when rights of way and digging permits over public land are granted by a single central authority and 0 when rights of way are granted by local authorities.

ROW2 A dichotomous variable taking the value of 1 when operators experience delays in getting rights of way or digging permits and 0 when no delays are reported.

LL12 A variable that measures the price of an unbundled copper local loop. It is obtained by adding one third of the one-off charge to the yearly fee (i.e. the yearly quota of the one-off

¹⁵Because, for example, not all the countries had mandated local loop unbundling as early as at the end of 2000.

charge).¹⁶

LLP A variable that measures the price of a leased line. It is obtained by adding the one-off fee to the annual charge of 2 kilometers 2Mbps leased line.

LCC The price of a ten minutes local call on the incumbent’s fixed network (including the call set-up fee).

Table 1: Summary statistics on DSL and alternative BB platform competition in Europe

	DSL			NODSL			INTRAPLAT			INTERPLAT		
	2001q2	2002q2	2003q2	2001q2	2002q2	2003q2	2001q2	2002q2	2003q2	2001q2	2002q2	2003q2
AT	69600	139300	232400	122000	246000	299000	0.88	0.70	0.66	0.54	0.54	0.51
BE	94000	361000	671300	180000	302000	418000	0.68	0.70	0.74	0.55	0.50	0.53
DE	1385000	2740000	4340362	24300	44000	70000	0.95	0.84	0.82	0.97	0.97	0.97
DK	74516	234902	390692	59034	122573	159064	0.51	0.66	0.71	0.51	0.55	0.59
ES	157702	661261	1300000	54000	210000	440000	0.78	0.66	0.63	0.62	0.63	0.62
FI	27400	120100	280000	25000	40000	63000	0.59	0.72	0.66	0.50	0.63	0.70
FR	177000	730800	2062000	163302	233579	338920	0.82	0.89	0.56	0.50	0.63	0.76
IE	0	1200	4900	5320	6800	9150		1.00	0.64	1.00	0.75	0.55
IT	239000	615000	1481000	14500	104000	247000	0.51	0.57	0.56	0.89	0.75	0.76
LU	550	2770	9550	20	100	205	1.00	0.93	0.93	0.93	0.93	0.96
NL	62000	250000	593000	300000	605000	850000	0.94	0.64	0.57	0.72	0.59	0.52
PT	1000	7120	105110	55765	150453	364110	0.91	0.60	0.68	0.97	0.91	0.65
SE	93765	337815	484900	165250	271000	321000	0.96	0.66	0.62	0.54	0.51	0.52
UK	72000	288900	1071700	76892	455994	1096036	0.58	0.52	0.50	0.50	0.53	0.50

In Table 1 we present some statistics on the evolution of inter and intra platform competitiveness in the considered European countries over the time considered by our analysis.¹⁷ The table shows a general trend toward a more competitive DSL market. In fact, apart from a few exceptions – namely Belgium, Denmark, Finland, and Italy – all countries have experienced increasing levels

¹⁶We are therefore distributing the common cost of the one-off charge over three years.

¹⁷Table 1 shows only three time observations of the 14 time observations of our dataset.

of competition in the DSL segment of the market. The dynamic of inter-platform competition is generally slower than the dynamic of intra-platform competition. This can easily be explained by the magnitude of the investments necessary to deploy alternative infrastructures.

5.2 Econometric specification and estimation results

In order to test the implications of the theoretical model presented above, an econometric analysis has been conducted, based on the evidence obtained for the EU countries mentioned in the previous section. In particular, the following models have been estimated

$$\begin{aligned}
\text{PENBB}_{i,t} = & \text{const} + \text{time effects} + \beta_1 \text{LLP}_{i,t} + \beta_2 \text{LL12}_{i,t} + \beta_3 \text{LCC}_{i,t} \\
& + \beta_4 \text{ROW1}_{i,t} + \beta_5 \text{ROW2}_{i,t} + \beta_6 \text{INTRA}_{i,t} + \beta_7 \text{INTER}_{i,t} \\
& + \beta_8 \text{INTER}_{i,t} * \text{LLP}_{i,t} + \beta_9 \text{INTER}_{i,t} * \text{LL12}_{i,t} + \varepsilon_{i,t},
\end{aligned} \tag{2}$$

$$\begin{aligned}
\text{PENBB}_{i,t} = & \text{const} + \text{time effects} + \beta_1 \text{LLP}_{i,t} + \beta_2 \text{LL12}_{i,t} + \beta_3 \text{LCC}_{i,t} \\
& + \beta_4 \text{INTRA}_{i,t} + \beta_5 \text{INTER}_{i,t} + \beta_6 \text{INTER}_{i,t} * \text{LLP}_{i,t} \\
& + \beta_7 \text{INTER}_{i,t} * \text{LL12}_{i,t} + \varepsilon_{i,t}
\end{aligned} \tag{3}$$

and

$$\begin{aligned}
\text{PENBB}_{i,t} = & \text{const} + \text{time effects} + \beta_1 \text{LLP}_{i,t} + \beta_2 \text{LL12}_{i,t} + \beta_3 \text{LCC}_{i,t} \\
& + \beta_4 \text{INTRA}_{i,t} + \beta_5 \text{INTER}_{i,t} + \beta_6 \text{INTER}_{i,t} * \text{LLP}_{i,t} \\
& + \beta_7 \text{INTER}_{i,t} * \text{LL12}_{i,t} + \beta_8 \text{GDPPC}_{i,t} + \varepsilon_{i,t},
\end{aligned} \tag{4}$$

where $\varepsilon_{i,t}$ is an error term and model (4) controls for GDP per capita (in real terms). Models (2), (3) and (4) can be estimated using well known panel data techniques. Time trend components have been accounted for including time effects in the estimated equations. As for the constant term, both the fixed effects and random effects specifications have been estimated and tested. The results of the estimation exercise, reported in Table 2, reveal some interesting facts and provides answers to the implications of the theoretical model of Section 4.

First, as predicted by Remark 1, the price of the local loop unbundling has a negative effect on the diffusion of the broadband. This confirms the importance of local loop unbundling, which is

Table 2: Panel regression results (figures in parentheses refer to t statistics for coefficients and to p values for tests)

Model	Model (2)		Model (3)		Model (4)	
Specification	FE	RE	FE	RE	FE	RE
LLP	-.000011 (-2.02)	-.000011 (-2.14)	-.000011 (-2.10)	-.000011 (-2.32)	-.000012 (-2.48)	-.000011 (-2.30)
LL12	-.001159 (-4.25)	-.001023 (-4.31)	-.001139 (-4.19)	-.001072 (-4.43)	-.000939 (-3.44)	-.001081 (-4.40)
LCC	.001024 (1.77)	.000427 (1.08)	.000383 (1.01)	.000275 (0.84)	.000346 (0.94)	.000291 (0.87)
ROW1	.007346 (0.85)	.005562 (0.75)				
ROW2	.018847 (1.56)	.008791 (0.90)				
INTRA	-.004376 (-0.24)	-.000181 (-0.01)	-.000444 (-0.02)	-.000115 (-0.01)	.016601 (0.89)	-.000235 (-0.01)
INTER	-.535053 (-4.79)	-.475339 (-4.86)	-.524846 (-4.71)	-.501873 (-5.05)	-.445346 (-3.99)	-.504741 (-5.00)
INTER * LLP	.000014 (1.88)	.000014 (2.01)	.000015 (2.08)	.000015 (2.27)	.000014 (2.11)	.000015 (2.25)
INTER * LL12	.001520 (4.00)	.001345 (3.88)	.001500 (3.94)	.001419 (4.09)	.001243 (3.27)	.001430 (4.07)
GDPPC					.617488 (2.70)	.001718 (0.06)
CONST	.371429 (4.59)	.355808 (4.97)	.398657 (5.13)	.385464 (5.49)	-5.998171 (-2.53)	.369452 (1.82)
R^2	0.50	0.57	0.57	0.57	0.02	0.57
LM test		76.82 (0.00)		173.82 (0.00)		164.08 (0.00)
Hausman	1.18 (1.00)		8.21 (0.31)		6.96 (0.32)	
Wald (joint)	32.91 (0.00)	427.62 (0.00)	39.74 (0.00)	419.39 (0.00)	39.01 (0.00)	413.45 (0.00)

one of the main strategies adopted by competitive broadband access providers in the DSL segment of the market: the price that they pay for each unbundled line affects directly their operating costs.

Also, strictly related to this finding is the negative and significant effect of the price of leased lines. These are in fact an important input for the provision of DSL services and therefore are expected to be inversely related to the diffusion of broadband services.

The price of local calls is, as expected, positively related with the diffusion of broadband. In fact, being the primary vehicle through which narrow band Internet access is provided, an increase in the price of local calls should push customers towards the adoption of broadband access to the internet. The sign shows that the price of narrow band Internet access constrains the diffusion (through the price) of broadband access, suggesting that, at least to a certain extent, narrow band and broadband access services are in the same relevant market; but the fact that the coefficient is not statistically significant confirms some previous findings in related literature that place the two products in separate markets.¹⁸

The coefficient related to the first Rights of Way variable has the expected sign (in fact one should expect less delay under centralised authority granting rights of way to broadband access providers), but is not statistically significant and it seems that, at least at this stage, centralisation of provision of the rights of way has not played a significant role in the diffusion of broad band technology. The second coefficient related to the granting of the Rights of Ways has instead the opposite sign to the one expected; but the coefficient is once again not statistically significant, and the variable indicating the concession of Rights of Way are dropped in the alternative specifications of models (3) and (4).

The Herfindhal Index expressing the level of competition between alternative technological platforms is negative and statistically significant. This confirms the findings of the theoretical model, namely those of Remark 3. Therefore competition between different platforms seems to be one of the main drivers of broadband uptake. This is an interesting result and it provides a statistical support to what has been often claimed by industry experts (see DotEcon and Criterion Economics, 2003).

The Herfindhal Index expressing the level of competition within each technological platform (in this case, due to data availability, only competition within DSL has been taken into account) is negative, as expected, but insignificant. Also, the coefficient is numerically very close to zero; this supports the theoretical prediction provided in Remark 3. Accordingly, although competition between DSL firms can potentially play an important role in promoting broadband diffusion, this

¹⁸DotEcon and Criterion Economics (2003) indicate that the extent of substitutability between narrow band and broadband access services is quite limited and only in the direction from narrow band to broadband; in any case, it is insufficient to suggest that they lie in the same relevant market. Similar evidence is in Hausman et al. (2001).

effect seems to be completely overwhelmed by the negative effect that the price of LLU has on broadband diffusion. Based on the empirical evidence provided and on the theoretical implications of Remark 3, the price of the LLU, which is a variable cost for DSL providers, seems to be still fixed at a high level; therefore increasing competition among DSL firms does not influence very much the broadband uptake unless the higher degree of competition is matched with a reduction of the LLU price. This consideration suggests that, given increasing competition within the market for DSL providers, a successful policy measure to boost broadband adoption and diffusion would be that of exercising further pressure to decrease the price of LLU.

The terms involving cross products between the LLP, LL12 and the inter-platform measure of competition are both positive and significant. This implies that the negative effect on broadband diffusion of the mentioned prices will be less severe for high level of concentration across the markets. The implications of these empirical findings seem to be consistent with the theoretical predictions of the model. In particular, under Scenario 2, which is the case more closely describing the actual situation of the broadband market, it is possible that the stimulating effect of a reduction in the price of LLU will be hampered by a high level of competition between technological platforms, as predicted in Remark 2.

Finally, it is worth noticing that the value and significance of the estimated parameters remain fairly constant across the different specifications estimated.¹⁹ In particular, for models (2), (3) and (4), the outcome of the Hausman test reveals that the random effect specification is the one consistent with data. In fact in all the cases the null hypothesis that there is no systematic difference between the two different (random and fixed effects) estimators is accepted. Also, the null hypothesis of no random effects is clearly rejected using the reported LM (Breusch and Pagan type) test.

6 Conclusions

This paper focuses on the distinct role played by inter-platform and intra-platform competition in stimulating broadband adoption. This is one of the most debated issues in the digital economy among both practitioners and policy makers.

¹⁹The only exception to this is the constant term in the fixed effect specification of model (4), which is anyway rejected by the Hausman test in favour of the random effect specification.

While stimulating entry into the DSL segment of the market through appropriate regulatory policies, such as local loop unbundling, is generally less problematic than enticing entry into alternative platforms (typically cable and fiber optics), it is still very much unclear which is the most effective way to proceed in order to speed up broadband adoption.

By moving from a simple model of oligopolistic competition between access providers of different platforms, we explicitly estimate the impact of intra-platform and inter-platform competition on broadband uptake. Our empirical evidence, based on data for 14 European countries, confirms all the theoretical predictions of the model; in particular, our estimations emphasise the role of stronger competition across technologies as the main driver to stimulate broadband adoption. Conversely, the enhanced competition within the DSL segment of the market does not seem to have played a similar role; furthermore, we have also shown, both theoretically and empirically, that there are positive synergies to be exploited between policies directed to induce more inter-platform competition and those directed towards local loop unbundling.

We view our results as a first step at understanding the effects of various forms of competition on broadband adoption. The adoption process is clearly at its early stages; should more complete data become available, we will investigate further on these complex relationships.

References

- Aron, D. J. and Burnstein, D. E. (2003). Broadband adoption in the united states: an empirical analysis. Paper presented at the the 31st Research Conference on Communication, Information and Internet Policy (Arlington, VA, USA).
- Bauer, J. M., Gai, P., Kim, J., Muth, T. A., and Wildman, S. S. (2003). Broadband uptake in oecd counries. Paper presented at the 31st Research Conference on Communication, Information and Internet Policy (Arlington, VA, USA).
- Crandall, R. W., Hahn, R. W., and Tardiff, T. J. (2002). The benefits of broadband and the effect of regulation. In Crandall, R. W. and Alleman, J. H., editors, *Broadband: Should We Regulate High-Speed Internet Access?*, chapter 13, pages 295–330. Brookings Institution Press, Washington D.C..
- DotEcon and Criterion Economics (2003). Competition in broadband provision and its implications for regulatory policy. A report for the Brussel Round Table.
- Garcia-Murillo, M. and Gabel, D. (2003). International broadband deployment: The impact of unbundling. Paper presented at the the 31st Research Conference on Communication, Information and Internet Policy (Arlington, VA, USA).
- Hausman, J. A., Sidak, J. G., and Singer, H. J. (2001). Cable modems and dsl: broadband internet access for residential customers. *American Economic Review*, 91:302–307.
- OECD (2001). The development of broadband access in oecd countries. Working Party on Telecommunication and Information Services Policies.
- OECD (2002). Broadband infrastructure deployment: The role of government assistance. Working Party on Telecommunication and Information Services Policies.
- OECD (2003a). Broadband update driving growth: Policy responses. Working Party on Telecommunication and Information Services Policies.
- OECD (2003b). ICCP Broadband update. Working Party on Telecommunication and Information Services Policies.

- Rappoport, P. N., Kridel, D. J., and Taylor, L. D. (2002). The demand for broadband: Access, content, and the value of time. Working paper presented at the Southern Methodist University economics workshop.
- Shy, O. (1995). *Industrial Organization. Theory and Applications*. The MIT Press, Cambridge, Mass.
- Stanton, L. J. (2004). Factors influencing the adoption of residential broadband connections to the internet. *IEEE Conference Proceedings*. Proceedings of the 37th Hawaii Conference on System Sciences.
- Varian, H., Litan, R. E., Elder, A., and Shutter, J. (2002). The net impact study v.2. Document available at www.netimpactstudy.com.

Mathematical appendix.

Proof. of Remark 1. Since $\beta > \gamma$, Remark 1 can be easily proved by simple differentiation of expression (1):

$$\frac{dBB}{dc} = -\frac{n(\beta(m+1) - \gamma m)}{\beta^2(1+n)(1+m) - \gamma^2 mn} < 0. \quad (5)$$

□

Proof. of Remark 2. The derivative in (5) depends on n and m . To prove Remark 2, take the total differential of (5):

$$d\left(\frac{dBB}{dc}\right) = \frac{\delta\left(\frac{dBB}{dc}\right)}{\delta n} dn + \frac{\delta\left(\frac{dBB}{dc}\right)}{\delta m} dm. \quad (6)$$

Now consider the realistic Scenario 2 explained above: then $dm > dn > 0$ and $dHHI_{inter} < 0$; this last inequality implies that in order to have

$$\frac{d\left(\frac{dBB}{dc}\right)}{dHHI_{inter}} > 0$$

the total differential given in expression (6) must be negative. Taking the derivatives of (5) with respect to n and m , it follows that

$$\frac{\delta\left(\frac{dBB}{dc}\right)}{\delta n} = -\frac{(\beta + m(\beta - \gamma))\beta^2(m+1)}{(\beta^2(m+n+nm) + mn(\beta^2 - \gamma^2))^2}$$

and

$$\frac{\delta\left(\frac{dBB}{dc}\right)}{\delta m} = \frac{(\beta + n(\beta - \gamma))\gamma\beta n}{(\beta^2(m+n+nm) + mn(\beta^2 - \gamma^2))^2}.$$

Plugging these expressions into (6) and rearranging, it is easy to see that $d\left(\frac{dBB}{dc}\right) < 0$ for

$$\frac{dn}{dm} > \frac{n\gamma(\beta + n(\beta - \gamma))}{\beta(m+1)(\beta + m(\beta - \gamma))}.$$

Since $dm > dn > 0$, it is easy to check that this condition can be satisfied for β significantly different from γ and/or n not too much bigger than m . This proves the remark.

□

Proof. of Remark 3. Consider the impact of intra-platform competition first. Under the adopted symmetric framework, $HHI_{intra} = 1/n$, and therefore

$$\frac{dBB}{dHHI_{intra}} = \frac{dBB}{dn} \frac{dn}{dHHI_{intra}} = -\frac{dBB}{dn} n^2.$$

Taking the derivative of (1) with respect to n yields

$$\frac{dBB}{dn} = \frac{\beta(\beta + m(\beta - \gamma))(\beta(\alpha - c)(m+1) - \alpha\gamma m)}{(\gamma^2 mn - \beta^2(n+1)(m+1))^2}. \quad (7)$$

This derivative is always nonnegative for all the admissible values of c ;²⁰ this is enough to prove that total broadband increases as the Herfindhal index on intra-platform competition decreases. Consider now the impact of inter-platform competition on broadband adoption; totally differentiating (1)

$$\frac{dBB}{dHHI_{inter}} = \frac{dBB}{dn} \frac{dn}{dHHI_{inter}} + \frac{dBB}{dm} \frac{dm}{dHHI_{inter}}. \quad (8)$$

Again, we want to study the sign of this expression under Scenario 2, that is when $dm > dn > 0$ and $dHHI_{inter} < 0$. Then taking the derivative of (1) with respect to m

$$\frac{dBB}{dm} = \frac{\beta (\beta + n (\beta - \gamma)) (\alpha \beta (n + 1) - \gamma (\alpha - c) n)}{(\gamma^2 mn - \beta^2 (n + 1) (1 + m))^2}.$$

This derivative is clearly positive for any $c \geq 0$; since $dBB/dn > 0$, $dm > dn > 0$ and $dHHI_{inter} < 0$, expression (8) is always negative.

To prove the last part of the remark, it is enough to see that for sufficiently high values of the price for the local loop,²¹ dBB/dn tends to zero and so does $dBB/dHHI_{intra}$. At the same time, simple visual inspection shows that (8) is still negative even if $dBB/dn = 0$. \square

²⁰It is easy to verify that in order to guarantee positive market shares to DSL firms, the price of local loop cannot be too high. Formally, $q \geq 0$ for $c \leq \bar{c}$. The intuition is straightforward.

²¹For c approaching $\bar{c} = \frac{\alpha (\beta + m (\beta - \gamma))}{(m + 1) \beta}$.