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Broadband Regulation: An Empirical Assessment

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Abstract

This paper provides an empirical assessment of the broadband policy of the European Union. In particular, we assess in more detail the effects of mandatory local loop unbundling on several market dimensions. We find that it has benefited broadband adoption through significant quality improvements. However, we also find that other regulatory features outside the scope of the new regulatory framework hinder broadband development in a significant manner.

Keywords: Regulation, Market Integration, Broadband.

JEL Classification: L51, L96, K23.

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1 Introduction

Developments in the broadband market are followed with increasing interest by policymakers given their important role in determining a country's level of infrastructure for information technologies and hence, its effects on growth and on the extension of the digital divide. On top of this, this market is at the heart of the convergence revolution that is reshaping the borders of traditional telecommunications and broadcast markets. By bundling internet access with telephony services, and lately with the broadcasting of video contents, players in the broadband market become strong entrants with the possibility to challenge the dominant position of old telecommunication incumbents. Indeed, the mixed results of the first set of regulatory measures adopted by the European Commission, the "1998 framework", suggest that the ultimate reasons behind the increased level of competition have to be found in the intense innovation process that has led to the convergence of communication technologies¹. In this respect, one should worry about any policy that may compromise convergence and, as a consequence, broadband development.

The present paper complements previous analysis of the liberalization strategy in the EU with an empirical assessment of the regulations affecting the broadband market, focusing in particular in the mandatory unbundling of the local loop. This policy was already introduced in the "1998 framework", it is further encouraged in the "New Electronic Communications Framework" of 2003 and gains relevance with the development of new network infrastructures. The assessment of its effects is all the more important given the higher level of policy harmonization sought by the Commission.

Hence, on top of other regulatory instruments, the analysis puts special emphasis on identifying the role of unbundling, access prices and National Regulatory Agencies (NRAs) in the development of broadband telecommunications. To do so, it focuses on their effect on broadband adoption, incumbent retail prices and infrastructure investment. Results show that mandatory unbundling has benefited broadband adoption through a significant effect on broadband quality, although this effect is very dependent on the level of access prices. We also find that other regulatory

¹In a companion paper (Gual and Jódar-Rosell (2007)), we review the liberalization strategy implemented by the European Commission. The analysis focused on the performance of the the first set of regulatory measures adopted by the Commission, which formed the "1998 framework", and later discussed their revisions and amendments that gave birth to the "New Electronic Communications Framework" in 2003.

features outside the scope of the new regulatory framework - such as public ownership of the incumbent and its cross-ownership of cable assets - hinder broadband development in a significant manner.

2 Regulatory Overview

Mandatory local loop unbundling (LLU) and the regulation of access prices constitute the two main instruments of regulatory intervention in the broadband market. The local loop is the infrastructure connecting the premises of the consumer to the telecommunications network. Essentially, LLU forces the owner of the local loop to satisfy any competitor's request for access to this infrastructure in exchange of an access price. Hence, competitors do not need to build their own infrastructure to reach the consumer and can use that of the incumbent instead. LLU regulations differ in aspects such as how close to a consumer a competitor can access the incumbent's network and who manages the competitor's equipment installed in the incumbent's premises (collocation rules)².

When designing the regulatory framework for telecommunications which mandated LLU, the European Commission favoured the hypothesis of the "ladder of investment" (see Cave (2003)). According to this hypothesis, new entry into the broadband market is favoured by granting the entrants the use of the incumbent's network assets at a regulated price. By doing so, entrants are given the opportunity to build a customer base which will provide them with the necessary cash-flow to incur in infrastructure investments. The assumption made is that, at an initial stage, broadband access services and resale are complements to investment in infrastructure. Hence, the possibility of service-based competition will trigger more facilities-based competition, reducing retail prices and enabling a greater variety of products.

The risk is that this hypothesis is false or, even if it is not, that access prices are set too low, thereby reducing the incentives for infrastructure investment. In this case, service-based competition would be a substitute for facilities-based competition and there would be a trade-off between short- and long-run welfare. Recognizing this trade-off, countries such as New Zealand, Switzerland or Mexico did not mandate LLU. Others introduced LLU with a sunset clause (Canada) or have reconsidered the extension of unbundling obligations (USA). Regarding the regulation of access

²See Wallsten (2006), OECE (2003).

prices to the local loop, there is substantial variation in the approach taken. The options range from simple cost orientation, with no cost methodology specified, to long-run incremental costs, retail-minus regulation or benchmarking. This kind of variation can also be found for the regulation of the incumbents' wholesale offers for simple resale.

Besides local loop regulations, existing regulations or certain institutional settings in adjacent markets may have an effect as well on the development of broadband. This is specially the case of cross-ownership regulations between telecommunications and the cable television sector. Cross-ownership may delay the emergence of facilities-based competition, helping the incumbent to leverage its dominant position to the broadband market. OECD (2003) provided evidence that "broadband markets [...] are being held back where cable networks are not providing independent competition with the PSTN".

Government ownership of the telecom incumbent can also play a significant role. Besides its possible improvement of productivity, less government participation may indicate a greater commitment to the liberalization process and the introduction of competition (Estache et al (2006)). On the other hand, a government-owned firm may pursue strategies which are not profit maximizing but can satisfy other social objectives. Given the importance placed in broadband infrastructure by policymakers, government ownership may help to overcome the incentive problem related to investment.

The empirical literature on broadband regulation has mainly sought to quantify the contribution to broadband diffusion of facilities-based competition versus that of pure resale of the incumbent services. The results point unambiguously to a positive role of facilities-based competition whereas those for resale deserve more qualification. Aron and Burnstein (2003) find that a state's adoption level is significantly affected by the fraction of population who can chose between two platforms, but not by the fraction of population who can access broadband services through a single platform (DSL). For the European countries, Distaso et al (2004) find that competition between DSL providers does not significantly encourage adoption but this effect seems to be due to high prices for the local loop, which have a significant negative sign. When looking at the speed of diffusion, Denni and Gruber (2005) find that intra-platform competition increases the initial availability of broadband but decreases the diffusion speed. Finally, Wallsten (2006) analyzes different forms

of unbundling and concludes that an extensive form³ (sub-loop unbundling) is robustly negatively correlated with broadband penetration whereas a less extensive one (loop unbundling) shows no robust pattern. Interestingly, the author finds that the rules dictating the form of access to the incumbent's infrastructure also matter, with those preventing non-price discrimination by the incumbent having a positive correlation with broadband penetration.

The empirical literature on the effects of regulatory interventions on telecommunications investment is scarce and has focused mainly in the role of access prices in the US. Given the low number of studies and their focus on the action of different types of players, no general conclusion can be extracted from them. Willig et al (2002) focus on the investment incentives of incumbent local exchange carriers (ILECs). Their reduced form approach finds that lower access prices to the local loop are associated with higher entry of competitive local exchange carriers (CLECs) and higher ILEC investment. The authors interpret this result as evidence in favour of the hypothesis that lower access prices induce network investment by increasing demand and competitive pressure from CLECs. Zarakas et al (2005) calibrate, instead, a dynamic oligopoly model and analyze the investment decisions of three types of facilities-based players and one pure reseller. In their model, investment is used to reduce variable costs of production and/or to increase service quality. The average revenue per line of each carrier depends, then, on the capital stocks of each of the carriers. The simulation of increases in loop prices results in facilities-based carriers increasing their investment levels while pure resellers decrease them. Finally, Beard et al (2005) analyze CLECs' investment in switching through a two-stage game. CLECs first decide whether to enter or not and, conditional on entry, the optimal amount of switching to self-supply (as opposed to the use of the incumbent's local loop plus its local switching services). Their results indicate that higher loop rates discourage CLECs investment in their own switching equipment. The decrease in the overall level of CLEC investment is attributed to a decrease in the number of CLECs in the market that more than offsets the increased investment of those who enter.

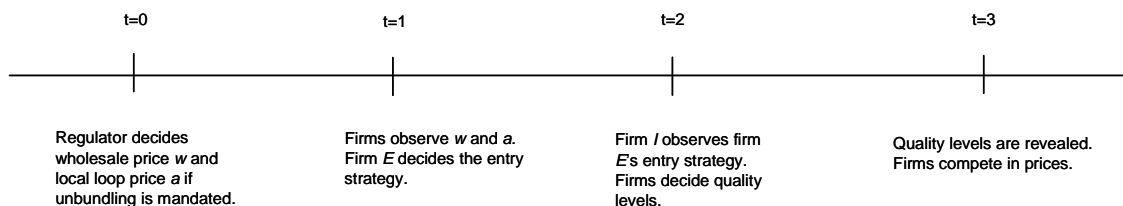
³Sub-loop unbundling allows the entrant to gain access to the incumbent's network at an intermediate point between the customer location and the incumbent's facilities (i.e. at the street level cabinets). See OECD (2003).

3 A Conceptual Framework

Given the basic trade-off between short- and long-run welfare faced by regulators, we propose to assess the effects of broadband regulation focussing our analysis on three performance measures that differ in the time period needed to reflect regulatory changes: prices, investment and diffusion. Price is the most immediately available instrument for broadband providers to adjust to changes in the regulatory setting. It can be easily adjusted to reflect a stronger competitive constraint placed by competitors, new entry or new access prices. On the other hand, investment is a longer term strategic decision and involves more commitment for firms. Finally, broadband diffusion will respond to regulatory changes through the combination of their effects on prices and investment over time.

In order to get some intuition on the possible determinants of each of these three variables, as well as on the possible relationships between them, consider the following simplified model played by the incumbent and one entrant in a regulated environment. Both firms are engaged in a two-stage game in which they compete in prices in the second stage and decide on investment in the first stage. Investment in infrastructure improves the quality of the product and enables increased horizontal differentiation. Moreover, investment can signal a commitment to stay in the market, which may further increase the demand for the firm's product. For non-incumbent players, the range of quality levels to choose from depends on their selected entry strategy. In other words, entrants must decide whether it is in their best interest to build their own infrastructure, to use the incumbents' local loop or to simply resale the incumbent's product, in view of the degree of product differentiation offered by each alternative and the structure of access prices set by the regulator. This framework fits well within the duopoly model of product innovation with dependent characteristics proposed by Degryse and Irmen (2001). In their model, firms are vertically and horizontally differentiated and the quality characteristics of the product affect the degree of horizontal differentiation. Next, we sketch a version of their model applied to the provision of broadband access.

Consider two firms I (incumbent) and E (entrant) that offer broadband access to the consumers. Following the discussion in the previous paragraph, the timing of the model would be as follows:



Hence, we assume that firms take the regulatory framework as given and that the incumbent cannot use quality strategically to select the type of entrant he will face at the final stage of the game.

In this last stage, firms are located at the endpoints of a line with length one and with consumers uniformly distributed over the line with density one. Every period, each consumer decides from which provider to seek access for a flat rate. Her indirect utility of subscribing access by brand j , $j \in \{I, E\}$, is given by the following expression:

$$V = v + s_j - p_j - (1 + \delta s_j)(z_j - z) \quad (1)$$

where v is gross surplus, s_j is the quality provided by firm j , p_j denotes the flat rate charged by firm j , δ is a parameter describing the interaction between the two dimensions of product differentiation, z_j gives the location of firm j in one of the ends of the line and z denotes the consumer preferred location. The term $(1 + \delta s_j)$ defines the per unit transport cost of buying firm's j product, whereas $(z_j - z)$ is a measure of the distance between the consumer's preferred connection type and that offered by the firm.

As in any discrete choice decision, consumers select their provider by comparing their indirect utilities under the two possibilities. The consumer indifferent between the two alternatives determines firms' demand functions. For the incumbent provider that would be:

$$\begin{aligned}
 D_I(p_I, p_E, s_I, s_E) &= \\
 &= \begin{cases} 1 & \text{for } p_E - p_I \geq 1 + s_E - s_I(1 - \delta) \\ \frac{1 + s_I - s_E(1 - \delta) + p_E - p_I}{2 + \delta(s_I + s_E)} & \text{for } 1 + s_E - s_I(1 - \delta) \geq p_E - p_I \geq s_E(1 - \delta) - s_I - 1 \\ 0 & \text{for } s_E(1 - \delta) - s_I - 1 \geq p_E - p_I \end{cases}
 \end{aligned}$$

Demand for the entrant is thus given by $D_E = 1 - D_I$. Firms compete in quality

and then price to maximize profits. Quality can be increased by investing a fixed cost given by $C(s_j) = fs_j^2/2$ and there is a constant marginal cost c_j of providing access. For player E , both c_E and the domain of s_E depend on his entry strategy. In particular, c_E can either be the regulated wholesale price, the regulated price of the local loop or the marginal cost of providing the service using his own infrastructure. We assume that firms take the regulated rates as given when deciding on prices and qualities.

Consider the case in which the entrant uses the local loop of the incumbent at a regulated access price a . The incumbent's profit function is thus as follows:

$$\Pi_I(p_I, p_E, s_I, s_E) = (p_I - c_I)D_I(p_I, p_E, s_I, s_E) - C(s_I) + (a - c_I)D_E(p_I, p_E, s_I, s_E)$$

Solving the game backwards, equilibrium prices are the solution to the system of equations formed by the first order conditions with respect to prices, taking quality levels as given.

$$p_I^*(s_I, s_E, a, \delta) = 1 + \frac{s_I(1 + \delta) + s_E(1 - 2\delta) + 2a}{3} \quad (2)$$

$$p_E^*(s_I, s_E, a, \delta) = 1 + \frac{s_E(1 + \delta) - s_I(1 - 2\delta) + 2a}{3} \quad (3)$$

Equilibrium quality levels $s_j^*(a, \delta, f)$ are then obtained by substituting (2) and (3) into the profit functions and solving the resulting system of first order conditions.

The other two cases can be obtained similarly. At stage 1, the entrant would decide his entry strategy by comparing his profits under each alternative: $\Pi_E^{resale}(w, \delta, f)$, $\Pi_E^{LLU}(a, \delta, f)$, $\Pi_E^{facility}(c_I, c_E, \delta, f)$. Accordingly, the observed entry strategy of the entrant will be the one yielding him higher profits and the observed quality offered by the incumbent will be that which best accommodates the entry of a competitor under such mode of entry.

4 Empirical Specification

The previous discussion helps to clarify the determinants and the relationship between quality and prices in equilibrium that we should expect to find in the data. On the one hand, conditional on the regulatory framework, incumbent's equilibrium prices are a function of the ancillary parameters of the model (gross surplus v and the interaction parameter δ), plus the observed qualities of all the players and the relevant cost variables c . In the event that the incumbent faces the three types of entrants in the last stage, these costs will include his own marginal costs, wholesale prices and the price for the local loop. In particular, we propose the following specification for incumbent prices in country i at time t :

$$\ln(\text{prices})_{it} = \alpha + \beta_1^p(c)_{it} + \beta_2^p(v)_{it} + \beta_3^p(\delta)_{it} + \beta_4^p(s)_{it} + \beta_5^p(\text{regulation})_{it} + \varepsilon_{it} \quad (4)$$

On the other hand, equilibrium quality levels depend again on the type of entrants through the wholesale or local loop prices and marginal costs (c), on the investment costs (f) and on factors determining the effect of quality on product differentiation possibilities. We thus propose the following specification:

$$\ln(\text{quality})_{it} = \alpha + \beta_1^s(f)_{it} + \beta_2^s(c)_{it} + \beta_3^s(v)_{it} + \beta_4^s(\delta)_{it} + \beta_5^s(\text{regulation})_{it} + \epsilon_{it} \quad (5)$$

Still, the simple model presented above assumes the market for broadband is fully covered, in the sense that all the consumers buy access from one of the two providers. In order to derive an expression characterizing the aggregate demand for broadband access, we assume that the consumer final decision is the combination of two simpler decisions: a) whether it is worth to have a broadband access and b) if so, which provider is preferred. Under this assumption, equation (1) is the indirect utility of the consumer conditional on having access. The gross surplus v includes then the valuation of broadband access characteristics that differentiate it from the outside alternative. Adding an unobserved shock that follows a generalized extreme value distribution, one can derive the marginal probability of an individual adopting broadband to get:

$$P_{broadband} = \frac{e^{v+\lambda I}}{1 + e^{v+\lambda I}}$$

where λI denotes the expected utility that a consumer receives from the choice among the possible broadband providers. Berry, Levinsohn and Pakes (1995) showed how these individual probabilities can be combined to obtain the aggregate demand for broadband. The resulting expression is similar to the epidemic model used by Gruber and Verboven, (2001) in their study of the diffusion mobile telecommunications. Our proposed specification for broadband demand in country i at time t is then:

$$\ln\left(\frac{adopters}{1 - adopters}\right)_{it} = \alpha + \beta_1^d(v)_{it} + \beta_1^d(\delta)_{it} + \beta_3^d \cdot \ln(prices)_{it} + \beta_4^d \cdot \ln(quality)_{it} + u_{it} \quad (6)$$

Prices and quality enter the demand equation as a proxy for the expected utility λI . On the other hand, since in equilibrium their levels are determined jointly with aggregate demand, they have to be considered as endogenous variables in this equation.

5 Data

We estimate this system of equations (4), (5) and (6) using data for the OECD countries less Turkey for the period 2001-2005. Due to missing observations for several variables in the early years of the sample, we end up with an unbalanced panel of 88 observations and 28 countries. Among these countries, some have not adopted a policy of mandatory LLU while the rest have adopted it at different moments of time. Data are drawn from several sources and are described in more detail in the appendix. Next, we discuss our measures for the endogenous variables.

5.1 Endogenous variables

The effect on broadband prices is analyzed using the incumbents' prices. Although those probably are not the cheapest offers available to consumers, they are a reaction to the more favorable terms offered by entrants. Broadband providers typically offer

a menu of options to consumers, with different prices and download speeds. In order to have a single homogeneous measure of price per country, we compute the average price per kbits per second that results from the menu offered by the incumbent in each country. For metered offers with caps on data transfers, we have followed Garcia-Murillo and Gabel (2003) and assumed an average monthly requirement of 1000 MB. These data is drawn from various issues of the OECD Communications Outlook.

The second performance measure that we analyze is the quality of local access, in order to test the ladder of investment hypothesis. To proxy for the overall level of this quality in each country, we use a measure of the investment outcome in a complementary product: international internet bandwidth per person. This variable is provided by the ITU as a measure of the "quality of the experience of the internet users within a country". International internet bandwidth refers to the capacity which backbone operators provision to carry internet traffic measured in bits per second. As such, it is the result of investments made by backbone operators, which may be different players from broadband providers. Nevertheless, this investment is likely to be complementary and highly correlated with the aggregate investment in local access.

Finally, the dependent variable in the equation for broadband demand is the logarithm of the fraction of broadband adopters over the number of potential adopters who have not yet adopted. This fraction is computed as the number of broadband subscribers per 100 inhabitants and it is drawn from various issues of the OECD Communications Outlook.

5.2 Control variables

Next, we describe the explanatory variables grouped by the ancillary parameters of the model which they proxy.

Proxies for gross surplus (v)

- GDP per capita ($\ln gdp_{cap_cons}$): it reflects differences in the willingness to pay across countries which may justify a higher overall level of prices.
- Personal computers per 100 inhabitants ($\ln pc$): since PCs and broadband

access form a system for accessing the internet, this variable reflects PCs users' higher valuation for a broadband connection.

- Percentage of the population aged 15-35 (*lnyouth*): due to higher skills and probably a better knowledge of foreign languages, one would expect young individuals to have a higher valuation for the service.
- Percentage of the population living in urban areas (*urban*): since a number of on-line services take advantage of the economies of density present in urban areas, people living in these areas may benefit from relatively more content/services and thus have a higher valuation for the good.
- Hosts with a country domain per capita (*hostpercap*): the higher the number of hosts that can be accessed, the higher the attractiveness of the contents/services that can be accessed through the broadband connection. From the total number of hosts, for each country we select those with the corresponding country domain in order to capture the existence of content accessible in the language of the country. This content may be more relevant to the marginal consumer than content in foreign languages.

Proxies for marginal costs (*c*)

- Population density (*popd*): the higher this number the greater the opportunity to exploit the economies of density existing in the installation, the upgrading or the laying of a new line to the customer's premises.
- Installed base (*Instbase*): scale economies and learning effects that lower the costs of maintenance inside the home can be captured through this variable, which is measured by the percentage of population having adopted broadband in the previous period.

Proxies for investment costs (*f*)

- Percentage of homes passed by cable (*catvpassed*): It reflects the investments that have already been made by cable providers. We expect a positive sign for two reasons: on the one hand, upgrading a network is usually cheaper than building a new one; on the other hand, there may be learning-by-doing effects in network deployment that lower the cost of deploying new lines.

- Government prioritization of ICT (*government*): given the growth implications of broadband infrastructure, it may be in the interest of governments to subsidize broadband deployment. Since no measure of the level of subsidies to broadband is available, we use survey data on the implication of government in ICT policies. We expect this variable to have a positive sign.
- Telecommunications stock market (*lnstock*): in order to capture the cyclical conditions which may influence investment decisions, we introduce this time varying variable that reflects the evolution of the telecommunications stock market and, hence, captures the effect of the burst of the telecom bubble.
- Experience of the competitors (*experience*): competitors with experience in adjacent markets, such as telephony, may benefit from learning-by-doing effects in network deployment or from better financial conditions.

Proxies for the interaction parameter (δ)

- Technological market concentration (*HHHtech*): the existence of different access technologies in a country is associated with a higher degree of product differentiation.

Regulatory variables Regarding the regulatory framework, we assess the impact of government ownership of the incumbent (*public*), of the possibility of cross-ownership between telecoms and cable (*crossown*) and of unbundling regulations. The effect of the latter can be analyzed from different perspectives, involving different measures related to unbundling:

- Mandatory LLU (*unbundling*): once controlling for differences in the other control variables, this dummy variable captures any difference in the average level of bandwidth or prices between those countries which have implemented LLU and those which have not at time t . The sample includes both countries which have not adopted a policy of mandatory LLU and countries which have adopted it at different moments of time
- Access prices for LLU (*lnacc_ull*): For those countries that have mandated LLU, we can assess the differential impact of unbundling depending on the

level of access prices set by the NRA. We do this by interacting the unbundling dummy with the access price.

Other controls

- Average household size (*lnhhsiz*e): since typically there is a single connection to the internet per household, the measure of internet bandwidth per person underestimates the amount of bandwidth available for households in countries with higher average household sizes.

5.3 Endogeneity issues

We assume the unbundling dummy variable to be uncorrelated to the error terms in (4) and (5), conditional on the other control variables. While it is true that the unbundling decision was taken in light of the state of development of the telecommunications industry in each country, we can consider it as a predetermined variable with respect to the broadband market. For most of the countries in the sample, the decision on whether to mandate LLU was either made prior to the launch of the commercial service by the incumbent or imposed by a supra-national authority (the European Commission).

The case of access prices is different. As the timing of the game in section 3 makes clear, access prices are set by the NRA following a locally determined rule, which will typically depend on the observed level of final prices and qualities. Thus, access prices are endogenous variables in the estimation. To control for this endogeneity, we need instruments correlated to this access charges but uncorrelated to retail prices or qualities. Access prices will be set by the NRA as a function of its information about the costs of the incumbent. Thus, good instruments for access prices should be given by variables capturing the ability of NRAs to extract information from the incumbent: years of experience, existence of separate accounts for the incumbent's activities, number of employees and the annual budget. Another source of instruments comes from variables correlated with the ability to credibly use this information, such as the independence of the NRA or its enforcement powers.

6 Results

Consider first the results for the base specification of the system formed by equations (4), (5) and (6), which are presented in the first three columns of table 1. Given the interrelations between the three endogenous variables in the system, changes in the exogenous variables have direct and indirect effects on the endogenous ones. The results in each column determine the direct effect. The indirect effect is given through the coefficient of the corresponding right-hand side endogenous variable.

A second complication for the interpretation of the results is given by the endogenous variable in equation (6). Recall this is the logarithm of the fraction of broadband adopters over the number of potential adopters who have not yet adopted. Hence, the results in the first column only provide an indication of the sign, and not the magnitude, of the elasticity of the fraction of adopters.

Consider first the adoption equation. The fit of the model is reasonably good, explaining around 69% of the variability in adoption. The results highlight the negative contribution of prices ($\ln pinc$) and the positive effect of broadband quality ($\ln bitspp$). The value of a broadband connection also increases with urbanization and the number of hosts per capita. The average price elasticity of broadband adoption is -0.64 ($-0.718 \cdot (1 - adopters)$) whereas the elasticity with respect to quality is 0.22 ($0.246 \cdot (1 - adopters)$). The coefficients on both variables imply that the average across countries of the value of quality in terms of money is 0.10 USD PPP per kbit of international bandwidth ($((0.248/0.718) \cdot (p/s))$) in 2004. This compares with an average price of a broadband connection of 0.8 USD PPP per kbit per second in the same year.

		Base Specification			Unbundling		
		<i>Adoption</i>	<i>Quality</i>	<i>Price</i>	<i>Adoption</i>	<i>Quality</i>	<i>Price</i>
<i>p</i>	lnpinc	-0.718*** (0.08)			-0.718*** (0.08)		
<i>s</i>	lnbitspp	0.246** (0.11)		0.266*** (0.10)	0.238** (0.10)		0.264*** (0.10)
<i>v</i>	lnpc	0.096 (0.23)	1.567*** (0.18)	-0.761*** (0.21)	0.106 (0.22)	1.560*** (0.16)	-0.728*** (0.20)
	hostpercap	3.798*** (1.06)	2.193* (1.32)	2.250* (1.25)	3.818*** (1.06)	2.427** (1.20)	2.066* (1.25)
	urban	1.888** (0.82)	-0.366 (0.82)	2.336*** (0.80)	1.877** (0.82)	-0.145 (0.75)	2.201*** (0.79)
	lnyouth	0.747 (0.98)	-4.822*** (1.35)	3.032*** (0.95)	0.715 (0.97)	-3.716*** (1.25)	2.608*** (0.94)
	lnhhsz		-1.223 (0.74)			-1.355** (0.69)	
<i>c</i>	popd		-0.001 (0.00)	-0.002** (0.00)		-0.001 (0.00)	-0.002** (0.00)
	lnstbase		-0.007 (2.01)	-15.955*** (1.83)		-0.607 (1.84)	-15.388*** (1.84)
δ	HHItech		-0.325 (0.48)	-0.859** (0.43)		-0.670 (0.44)	-0.769* (0.43)
<i>f</i>	catvpassed		1.423*** (0.37)			1.219*** (0.35)	
	lnstock		-3.072** (1.42)			-2.942** (1.31)	
	government		-0.330** (0.15)			-0.488*** (0.14)	
	experience		-0.109*** (0.02)			-0.104*** (0.02)	
<i>regul.</i>	public		-0.825*** (0.27)	0.053 (0.26)		-0.759*** (0.25)	0.018 (0.25)
	crossown		-0.206 (0.18)	-0.003 (0.16)		-0.392** (0.17)	0.104 (0.17)
	unbundling					0.828*** (0.19)	-0.342 (0.21)
	Constant	-7.579*** (1.28)	21.944*** (6.88)	-2.582** (1.22)	-7.535*** (1.26)	22.909*** (6.37)	-2.710*** (1.21)
	N	88.000			88.000		
	r2	0.687	0.808	0.680	0.688	0.842	0.689
	chi2	235.208	387.313	209.703	237.474	485.542	216.257
	p	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parenthesis

Legend: * significant at 10% level; ** significant at 5% level; *** significant at 1% level.

Table 1: The effects of regulation on broadband adoption, quality and incumbent prices

The model does a better job at explaining differences in quality across countries and time, with an R^2 of 0.81. Moreover, most of the significant coefficients have the

expected sign. First, the overall broadband quality in a country increases with the percentage of PC users and the number of hosts per capita, signalling their positive effect on the valuation of the good. Similarly, countries with a more extensive coverage of cable networks have higher quality levels, reflecting better initial conditions or scale economies in network deployment. Our results also confirm the negative effects of public ownership previously found in the literature, since overall quality decreases with the ownership share of public sector.

Some of the variables in the quality equation have, however, an unexpected sign. On the one hand, a higher percentage of young population decreases quality. The experience of the entrants also have a negative and significant effect. A possible explanation for these negative signs may be related to errors in the measurement of quality. According to the ITU, the amount of international bandwidth per person may underestimate the true level of broadband quality in those countries with lower needs of international connectivity. They mention several reasons to explain why a country needs fewer international connections: a) most of the accessible contents are created domestically; b) its language has very few speakers abroad; or c) it has a large domestic market. Some the countries with higher experience (US, Japan) or higher shares of young population (Korea, Slovakia) fulfill these requirements and may be driving the results. On the other hand, government prioritization of ICT sectors also have an unexpected negative sign. Nevertheless, this variable is constructed from survey responses and thus, reflects a subjective view on the matter that may not properly account for the level of subsidies to broadband deployment.

The third column in table 1 shows the determinants of the incumbent's prices. Again, the fit of the model is quite good, with an R^2 of 0.69. The first thing to notice is that the coefficient of quality is positive and significant. Hence, prices are indirectly affected by the quality determinants through this coefficient. As expected, differences in prices are explained by differences in marginal costs, captured through the negative coefficients of population density and the installed base. The higher valuation of urban consumers and the higher value of accessible content are also reflected in prices. More surprisingly, a higher PC penetration decreases the incumbent prices. Finally, evidence on the relevance of the interaction parameter δ is given by the coefficient on technological market concentration. An increase in δ , given by a decrease in technological concentration, increases the incumbent price. This is in line with the model proposed by Degryse and Irmen (2001).

	Direct effect on quality	Direct effect on prices	Total effect on adoption
lnpc	1.57%	-0.34%	0.56%
hosts	0.23%	0.29%	0.20%
urban	-	1.76%	0.14%
lnyouth	-4.82%	3.03%	-0.24%
popd	-	-0.27%	0.17%
Instbase	-	-1.17%	0.71%
HHItech	-	-0.52%	0.34%
catvpassed	0.78%	-	0.03%
government	-1.59%	-	-0.08%
experience**	-10.32%	-	-0.51%
public	-0.23%	-	-0.01%

Elasticities calculated as the average across countries in 2004.

(**) Effect of an extra year.

Table 2: Total effect on broadband adoption

As mentioned before, the exogenous determinants of price and quality will also have indirect effects on broadband adoption. Table 2 summarizes these effects in terms of average elasticities. It shows the percentage change on the endogenous variable of a 1% increase of the exogenous one. As an example, consider the effect of the percentage of urban population. This percentage has a positive direct effect on broadband adoption that is partially offset by a negative indirect effect through prices. A 1% increase in the percentage of urban population raises prices a 1.76% on average which, in turn, decrease broadband adoption a 1.12%. The total effect on adoption is a raise of a 0.14% on average $(-1.12\% + (urban * 1.88) * (1 - adopters))$.

The last three columns in table 1 account for the differential effect in quality levels and prices of mandatory local loop unbundling. Results show that unbundling only has a significant impact on quality, with countries where LLU is implemented having quality levels approximately 129% higher. This result, then, gives some support to the "ladder of investment" hypothesis since higher quality levels are associated with higher investment. Unbundling also affects prices, but only indirectly through the increased quality since the negative direct effect is not significant. Hence, the positive effect on adoption of a higher quality is partially offset by the corresponding increase in prices. The result is that unbundling raises broadband adoption a 6.5%.

The introduction of the unbundling dummy has the additional effect of improving the significance of the cross ownership coefficient in the quality equation. The ownership of cable assets by the incumbent decreases overall quality levels in a country a 32.4%

but also decreases prices indirectly a 8.6%. The result is a decrease in broadband adoption of a 1.63%.

The relative success of unbundling largely depends on getting the set of access prices right, both to promote the entry of efficient competitors and to induce the proper level of investment. The first three columns in table 3 try to determine whether the higher success of unbundling policies in some countries is due to a better pricing of access. To this end, we interact the unbundling dummy with the log of access prices for the local loop. In so doing, we lose observations from 4 countries⁴ and several years due to missing information on access prices. The results show that access prices have a negative effect both on quality and prices but only the latter effect is significant. A 1% increase in the price of local loop decreases prices a 0.51%. This negative effect could be the result of relatively better terms for entry through pure resale of the incumbent product, which would increase price competition. The final result on broadband adoption is an increase of 0.39% ($0.51 * (-0.871 * (1 - adopters))$).

As a robustness check, we repeat the estimation of this last specification but taking into account the possible endogeneity of access prices. To this end, we use three instruments that are significantly correlated with this variable: a) the experience of the NRA; b) whether the NRA has enforcement powers and c) whether the NRA members are appointed for fixed terms.

The results are shown in the last three columns of table 3. Although they should be interpreted with caution, given the reduced sample size, they seem to indicate that endogeneity problems are more important in the quality equation. The coefficient of unbundling nearly doubles in magnitude and that of access prices increases both in magnitude and significance. On the contrary, the coefficients in the price equation remain fairly similar but the effect of access prices is less precisely estimated. Hence, the results seem to confirm the positive role of unbundling at moderate access prices in the overall quality level of a country.

⁴These countries are Australia, Canada, Iceland and Norway.

		Access Price			Access Price IV		
		<i>Adoption</i>	<i>Quality</i>	<i>Price</i>	<i>Adoption</i>	<i>Quality</i>	<i>Price</i>
<i>p</i>	lnpinc	-0.871*** (0.11)			-0.988*** (0.13)		
<i>s</i>	lnbitspp	0.229** (0.11)		0.329*** (0.10)	0.060 (0.13)		-0.108 (0.11)
<i>v</i>	lnpc	-0.004 (0.24)	1.262*** (0.16)	-0.712*** (0.19)	0.181 (0.25)	0.977*** (0.20)	-0.186 (0.19)
	hostpercap	4.609*** (1.75)	2.688* (1.49)	-0.073 (1.60)	5.674*** (1.85)	0.905 (1.81)	3.516** (1.56)
	lnyouth	1.044 (1.01)	-3.171*** (1.14)	2.190*** (0.81)	0.358 (1.07)	-2.038 (1.44)	0.796 (0.77)
	urban	1.649* (0.88)	0.969 (0.66)	1.048 (0.73)	1.070 (0.94)	0.545 (0.79)	-0.275 (0.73)
	lnhsize		-1.793** (0.76)			-3.311*** (0.96)	
<i>c</i>	popd		-0.002*** (0.00)	-0.001** (0.00)		-0.001 (0.00)	0.000 (0.00)
	lnstbase		0.559 (1.97)	-15.289*** (2.15)		0.005 (2.34)	-16.957*** (2.14)
δ	HHIttech		-0.129 (0.40)	-1.299*** (0.43)		-0.106 (0.47)	-1.522*** (0.39)
<i>f</i>	catvpassed		1.360*** (0.31)			1.217** (0.47)	
	lnstock		-1.668 (1.26)			0.877 (1.50)	
	government		-0.328** (0.13)			-0.142 (0.18)	
	experience		-0.112*** (0.01)			-0.090*** (0.02)	
<i>regul.</i>	public		-0.521** (0.23)	-0.156 (0.26)		-0.364 (0.29)	0.167 (0.23)
	crossown		-0.648*** (0.15)	0.281* (0.16)		-0.619*** (0.16)	0.062 (0.15)
	unbundling		1.596** (0.65)	1.010 (0.74)		2.906** (1.40)	1.535 (1.14)
	LLUxlog(Accp)		-0.272 (0.23)	-0.508** (0.25)		-0.911* (0.50)	-0.545 (0.39)
	Constant	-7.515*** (1.32)	15.935*** (6.09)	-2.326** (1.09)	-6.635*** (1.39)	6.250 (7.18)	0.535 (1.09)
	N	73.000			68.000		
	r2	0.683	0.907	0.695	0.671	0.888	0.704
	chi2	188.508	721.304	179.321	175.203	544.262	177.173
	p	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parenthesis

Legend: * significant at 10% level; ** significant at 5% level; *** significant at 1% level.

Table 3: Explaining differences in the success of unbundling policies

As a final remark, we would like to signal that a shortcoming of this approach

is that an increase in the price of access to the local loop must be evaluated with respect to the access prices corresponding to other forms of entry (pure resale, shared access...), for which we do not have data. Since NRA are likely to set these prices taking into account the price of the local loop, the coefficients of the interaction term in the previous specification may be biased. A possible way to circumvent this problem would be to use the information on the forms of entry actually chosen by the competitors. They ultimately reflect the ability of the relative prices of access to induce a particular entry strategy. Moreover, they would allow us to quantify their relative importance for broadband adoption. Unfortunately, we only have this kind of data for 21 countries⁵, reducing considerably the sample and the reliability of the analysis.

7 Conclusion

As this paper has shown, there are still some regulatory features outside the scope of the "New Electronic Communications Framework" - such as public ownership of the incumbent and its cross-ownership of cable assets - that hinder broadband development. It is true, however, that this empirical analysis also shows that mandatory unbundling of the local loop seems to matter more than these features. Indeed, with the caution required by the small number of observations available for the analysis, we find support for the "ladder of investment" hypothesis. That is, unbundling seems to favour entry which translates into network investment once the entrants gain a substantial foothold in the marketplace. The overall effect of unbundling on broadband adoption cannot be ignored but it depends on the level of access prices. Lower prices strengthen the positive effects of unbundling on quality (and investment).

Finally, it must be stressed that the positive effect of mandatory unbundling should not be used to dismiss the risks posed by the present regulatory framework with respect to new generation networks. The present unbundling rules apply to an already deployed network whose functioning and potential are quite well understood. Contrary to the simple upgrade of the existing network, the deployment of a NGN comes along with significant changes in the management of the network and the need to redefine business models and pricing structures, and to coordinate in new

⁵In addition to the abovementioned 4 countries, we lose data for Japan, Korea and the US. We lose also some years for some countries due to missing information.

standards. In this respect, the identification of successful competitive strategies will be an evolutionary process that will benefit considerably from experimentation. This entails substantial risks for the operators and requires a predictable regulatory framework that does not impose the extension and harmonization of unbundling rules. The mandatory unbundling of a network which still has to be deployed and whose properties are not well understood is, in our view, one of the largest risks posed by the new regulatory framework.

References

- Armstrong, M. (1997), "Competition in Telecommunications", *Oxford Review of Economic Policy*, vol. 13 (1).
- Aron, D.J. and D.E. Burnstein (2003), "Broadband Adoption in the United States: An Empirical Analysis", paper presented at the 31st Research Conference on Communication, Information and Internet Policy, (Arlington, VA), September 2003.
- Beard, T. R., G. S. Ford and T. M. Koutsky (2005), "Mandated access and the make-or-buy decision: the case of local telecommunications competition", *The Quarterly Review of Economics and Finance*, vol. 45.
- Berry, S., J. Levinshon and A. Pakes (1995), "Automobile Prices in Market Equilibrium", *Econometrica*, vol. 63 (4).
- Cave, M. (2003), "The economics of wholesale broadband access", MMR Beilage 10/2003.
- Cave, M. (2007), "The regulation of access in telecommunications: a European perspective", *mimeo*, Warwick Business School, April 2007.
- Chang, H., H. Koski, S. Majumdar (2003), "Regulation and investment behavior in the telecommunications sector: policies and patterns in US and Europe", *Telecommunications Policy*, vol. 27.
- Crandall, R. (2005), "The Remedy for the Bottleneck Monopoly" in Telecom: Isolate It, Share It or Ignore It", *University of Chicago Law Review*, vol. 72.
- Degryse, H. and A. Irmen (2001), "Attribute dependence and the provision of quality", *Regional Science and Urban Economics*, vol. 31.
- Denni, M. and H. Gruber (2006), "The diffusion of broadband telecommunications: the role of competition", *Departmental Working Papers of Economics - University 'Roma Tre'* n° 60.
- Distaso, W., P. Lupi and F. Manenti (2004), "Platform competition and broadband adoption in Europe: Theory and empirical evidence from the European Union", paper presented at EARIE 2004.
- Edwards, G. and L. Waverman (2006), "The Effects of Public Ownership and Regulatory Independence on Regulatory Outcomes: A Study of Interconnect Rates in EU Telecommunications", *Journal of Regulatory Economics*, vol. 29 (1).

Estache, A., A. Goicoechea and M. Manacorda (2006), "Telecommunications Performance, Reforms, and Governance", *World Bank Policy Research Working Paper* n° 3822.

Farrell, J. and P. Klemperer (2006), "Coordination and Lock-In: Competition with Switching Costs and Network Effects", (May 1, 2006). *Competition Policy Center Paper* CPC06-058.

Gregg, (2006), "A survey of unbundled network element prices in the United States", National Regulatory Research Institute, Ohio State University.

Gruber, H. and F. Verboven (2001), "The Evolution of Markets Under Entry and Standards Regulation - the case of Global Mobile Telecommunication", *International Journal of industrial Organization*, vol. 19.

Gual, J. (2004), "Market Definition in the Telecoms Industry", in *The Economics of Antitrust and Regulation in Telecommunications*, edited by P.Rey and P. Buigues, E. Elgar Publishing, 2004.

Gual, J. (2007), "Integrating Regulated Network Markets in Europe", *"la Caixa" Economic Papers*, n° 5.

Gual, J. and S. Jódar-Rosell (2007), "European Telecoms Regulation: Past Performance and Prospects", *"la Caixa" Working Paper Series*, n° 04/2007.

Gual, J. and F. Trillas (2006), "Telecommunications Policies: Determinants and Impacts", *Review of Network Economics*, vol. 5 (2).

Hausman, J. and G. Sidak (2004), "Did mandatory unbundling achieve its purpose? Empirical evidence from five countries", MIT Working Paper 04-40.

Laffont, J-J. and J. Tirole (2000), *Competition in Telecommunications*, Cambridge, MA. MIT Press.

Li, W. and L. C. Xu (2004), "The impact of privatization and competition in the telecommunications sector around the world", *Journal of Law and Economics*, vol. 47.

Garcia-Murillo, M. and D. Gabel, "International Broadband Deployment: The Impact of Unbundling," paper presented at the 31st Telecommunications Policy Research Conference (Arlington, VA), September 2003.

OECD (2003), "Broadband and Telephony Services over Cable Television Networks", DSTI/ICCP/TISP (2003) 1, published in May 2003.

OECD (2003), "Developments in Local Loop Unbundling", DSTI/ICCP/TISP(2002)5/FINAL, published in September 2003.

Valletti, T. (2003), "The theory of access pricing and its linkage with investment incentives", *Telecommunications Policy*, vol. 27.

Valletti, T. and C. Cambini (2005), "Investments and network competition", *RAND Journal of Economics*, vol. 36 (2).

Vogelsang, I. (2003), "Price Regulation of Access to Telecommunications Networks", *Journal of Economic Literature*, vol. 41 (3).

Wallsten, S. (2003), "Of Carts and Horses: Regulation and Privatization in Telecommunications Reforms", *Journal of Economic Policy Reform*, vol. 6 (4).

Wallsten, S. (2006), "Broadband and Unbundling Regulations in OECD Countries", *AEI-Brookings Joint Center Working Paper* No. 06-16.

Willig, R., W. Lehr, J. Bigelow and S. Levinson (2002), "Stimulating Investment and the Telecom Act of 1996", Draft, Oct. 11, 2002.

Zarakas, W.P., G.A. Woroch, L.V. Wood, D.L. McFadden, N. Ilias and P.C. Liu (2005), "Structural Simulation of Facility Sharing: Unbundling Policies and Investment Strategy in Local Exchange Markets", The Brattle Group, July 2005.

Appendix A:

Competition and Investment in Broadband Telecommunications					
Data	Name	Variable	Year	Source	Comment
<u>Adoption of broadband technologies</u>	bbsubs_	Broadband subscribers per 100 inhabitants	2001-2005	OECD Broadband statistics 2006 -Time Series	
<u>Quality</u>	bandw_	Series Code: IT.NET.BNDW Series Name: International Internet bandwidth (Mbps)	1999-2004	World Development Indicators, 2006. World Bank. Data provided by ITU (Core ICT Indicators)	ITU Description: International Internet Bandwidth refers to the capacity which backbone operators provision to carry Internet traffic measured in bits per second. This indicator is intended to represent the quality of the experience of Internet users with
	bitspp_	Series Code: IT.NET.BNDW.PC Series Name:	1999-2004	World Development Indicators, 2006. World Bank. Data provided by ITU	
<u>Price of the incumbent</u>	pinc_	Internet access by DSL in OECD member countries	Sep 2002 & Nov 2004	OECD COMMUNICATIONS OUTLOOK 2005 – Table 6.16.	Monthly charge (USD PPP) / Speed of connection downstream (In case of unlimited mbytes included. Where the contract was a two-part tariff, 1Gb=1024Mbytes are assumed as an average usage per month) It's the mean of the different types of contracts offered
			for 2005	OECD - Multiple play: pricing and policy trends	Monthly charge (USD) / Speed of connection downstream kbit/sec
			for 2001	OECD - Broadband Uptake and Infrastructure Regulation: Evidence from the OECD Countries	
<u>Sociodemographic characteristics</u>	gdp	GDP	2001-2005	OECD Main Economic Indicators	Measures C: National currency, current prices, millions; VPVOB : US \$, constant prices, constant PPPs, OECD base year, millions
	pop	Population	2001-2005	OECD Main Economic Indicators	
	pc_	PC's per 100 inhabitants	1999-2005	ITU - ICT Statistics Database: Country data by region	
	youth_	% of people aged 15-35	2001-2006	LABORSTA Labour Statistics Database (ILO)	
	urban	% of urban population	2000-2005	WDI 2006, Urbanization Table 3.10	
	hhsiz	Average Household size	2000-2005	WDI 2006, Environment Table 3.11	
<u>Product characteristics</u>	hosts_	Internet hosts by domain	1998-2005	OECD COMMUNICATIONS OUTLOOK 2005 - Table 5.9 (www.ics.org Network Wizards)	Updated for 2005 using http://www.isc.org/index.pl?ops/ds/reports/2005-01/dist-byrum.php
<u>Access prices</u>	actfull_	Prices for full unbundled local loop	2001-2005	European Electronic Communications Regulation and Markets (11th, 10th, 9th & 8th reports) European Commission, Information Society. Data for 2001 taken from Annex to LLU Sectoral Inquire. Other sources for non EU: Gregg (2006); Outline of the Telecom. Business in Japan.	Charges for connection and the monthly rental per unbundled loop, for both full unbundled access and shared access to the loop
	acsharp_	Prices for shared access local loop	2001-2005		

<u>Interaction parameter</u>	HHItch	HHI of technologies	2001-2005	OECD Broadband statistics	
<u>Incumbent's cost</u>	popd_	Population density	1999-2005	ITU - ICT Statistics Database: Country data by region http://www.itu.int/ITU-D/ICTEYE/Indicators/Indicators.aspx#	Population density: Millions inhabitants/km2
<u>Investment cost</u>	catvpas	% homes passed by cable	2001	OECD - Broadband and Telephony services over cable television networks	
	government	Government prioritization of ICT	2001-2005	World Economic Forum - Global Competitiveness Report	
	Instock	FTSE All World DEVELOPED TELECOM Index	2001-2005	Datastream	
	experience	Years since first entry in telecom business	2001-2005	OECD International Regulation database and OECD Communications Outlook 2005	First entry defined as the year with positive market share of new entrants either in access lines or in trunk telephony.
<u>Regulatory variables</u>	crossown	Existence of cross-ownership between incumbent telecom and cable tv assets	2001-2005	OECD - Broadband and Telephony services over cable television networks	1 if incumbents telecomm carriers (partially) own cable companies in home market.
	public	% of government ownership of the incumbent operator	2001-2005	OECD International Regulation Database and OECD COMMUNICATIONS OUTLOOK 2005 - Table 2.7	
	unbundling	Mandatory unbundling implemented	2001-2005	OECD - Communications Outlook; OECD - Developments in LLU; NRAs ; ECTA Broadband Scorecard; Implementation Reports of the European Electronic Communications Regulation and Markets; ITU	1 if mandatory LLU is implemented in the country
<u>Instruments</u>	NRAexp	Experience of the NRA	2001-2005	ITU - http://www.itu.int/ITU-D/ICTEYE/Regulators/Regulators.aspx#	
	enforcement	Enforcement powers	--	ITU	1 whether the NRA has enforcement powers
	NRAfixed	NRA members appointed for fixed terms	--	ITU	1 if appointed for fixed terms
<u>Others</u>					
	ppp_	PPP	1980-2006	Purchasing Power Parities (PPPs) for OECD Countries 1980-2006	
	cpi_	Consumer Price Index	2001-2005	OECD Main Economic Indicators	Index 2000=100