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On the (in)effectiveness of policies to promote broadband diffusion in Europe (2003-2010): An econometric assessment*

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Abstract

This paper presents an updated empirical assessment of the relative effectiveness of intra-platform and inter-platform competition in terms of broadband diffusion in Europe between 2003 and 2010. It relies on an econometric analysis of 18 European countries. To approximate two forms of competition within a same platform, we distinguish between service-based access and facility-based access. The first type requires less investment from entrants than the second which allows entrants to differentiate their product. Our results update and validate earlier studies. We show that service-based intra-platform competition brought by access regulation is still not an accelerating factor of broadband diffusion (or investment) in Europe. In contrast, we find that both facility-based intra-platform competition brought by access regulation and inter-platform competition brought by the deployment of non-DSL technologies effectively fuels broadband diffusion. In sum, many EU countries may have underestimated the potential payoff of stimulating product differentiation through inter-platform and service-based intra-platform competition for the diffusion of broadband in Europe.

Key words: ICT, broadband diffusion, competition, regulation, EU

JEL codes: D43, L43, L63

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1. Introduction

The demand for access to information and telecommunication technologies (ICT) that fuels and gets fueled by the continuous development of technology intensive products and services seems to be endless. This is well understood by the European Commission and it has taken some pride in its commitment to stimulate the adoption of broadband to speed up the much needed productivity gains that meeting that demand could unleash.[1] Yet, recent research provides ample evidence of that not all policies have been as effective at stimulating broadband development. Without strategic policy changes, large shares of the population will continue to be excluded from the benefits of continuous technological changes (Samanta et al. (2012)). This is why the specific design of efforts to enable this development continues to be debated in policy circles.

One of the key dimensions of the debate is the extent to which the competitive and regulatory environments adopted have supported or slowed the development of broadband as seen in the recent survey by Cambini and Luang (2009). The evidence on what works and what does not is not as clear as sometimes argued and seems to depend quite a lot on the sample sizes, sample periods, modeling approaches and specific variable choices made to assess outcomes and controls. To see this consider the diversity of guidance provided by a representative sample of papers.

For a sample of 167 countries from 2000 to 2010, Gruber and Koutroumpis (2011) rely on a detailed technology diffusion model to assess broadband penetration rates. They account for the degree of competition through an Herfindhal index and for the diversity of regulatory approaches through a set of regulatory dummies. They find that inter-firm competition, in general, and intra-platform competition (competition on a same platform, i.e. on a same network) on the incumbent's Digital Subscriber Line (DSL) network[2], in particular, accelerate penetration rates. They find no evidence that inter-platform (competition across technologies, i.e. across networks) and intra-platform competition on cable have similar effects. They emphasize that retail competition is about as twice as effective as local loop unbundling in furthering diffusion for a period of 3-4 years. For a much smaller sample (20 countries) covering only OECD countries (i.e. only mature economies) from 2003 to 2008, Bouckaert et al. (2010) rely on a linear

[1] According to Babaali (2012), the European Commission, for example, estimates that every 10% increase in broadband penetration results in economic growth of between 1% and 1.5%.
[2] See Section 2 for more details.

model with random effects to explain penetration rates. They find, instead, inter-platform competition (approximated through an Herfindhal index) to be effective, in contrast to facilities-based intra-platform competition. Moreover, still in contrast to Gruber and Koutroumpis (2011), they find that service-based intra-platform competition is associated with slower broadband penetration. With a narrower sample of 14 European countries from 2000 to 2004, Distaso et al. (2006) find that inter-platform competition stimulated broadband penetration, but that competition in the DSL market did not play a significant role. More recently, Grajek and Röller (2011) present a dynamic model and analyze data from 70 operators of fixed lines in 20 EU countries from 1997 to 2006. They rely on a detailed modeling of the intensity of regulation, refocused the discussion of the impact of policy on investment rates on broadband. Their main finding is the negative impact on this investment of access regulation for that period.

What this diversity of results and methodologies suggests is that figuring out the most effective approach in a specific context is not simple. The policy environment not only needs to promote diffusion but it also needs to stimulate investments by incumbents and entrants. Moreover, the broadband market undergoes a constant evolution and it is a fast moving target. The more recent samples should reflect the fact that time gives the opportunity to adjust for intra-platform competition as much as it has for inter-platform competition. In that environment, Europe's challenge is essentially the need to continue to tailor its policies to ensure their ability to enhance the development of a sustainable and healthy competition while giving incentives to operators to keep investing and fostering the development of a new generation network of high performance.

The fact that the results are so sensitive to the time period and the number and types of countries covered, thus, suggests that to compare the effectiveness of strategies in the European context, the most desirable solution is to focus on a sample that covers only European countries. The sample should include a long enough period to reflect the time it takes to adopt new technologies as well the most recent period for which the required data is available to ensure that the latest adjustments are internalized.[3] This is why our empirical assessment of the most desirable option in the European context is anchored in a dataset for 18 European countries from 2003 until 2010.

[3] Belloc et al. (2011) show for instance that the relative impact of most factors usually considered to be drivers of broadband diffusion depend on the actual stage of diffusion.

We structure our analysis around DSL access and, following Bouckaert et al. (2010), we distinguish two forms of broadband access: service-based and facility-based. Service-based access requires less investment from entrants (an entrant retails mainly the same product as the incumbent). Facility-based access is meant to lead to more investment as entrants use it to differentiate their product.

As many other broadband markets, the European market is characterized by quite a high degree of concentration among providers. In most countries, the bulk of the markets are shared by four or less key players.[4] To reflect this fact, we focus on the share of the four main types of suppliers (classified according to their technology) in the total number of broadband lines supplied. We take this approach because it gives us a sense of the revealed preferences by the market induced by the regulatory design. The more a share of a provision type changes, the more regulation has been favoring or penalizing that source of provision of broadband services. This specification enables more direct conclusions on the role of each type of supplier than an Herfindhal index would allow us to do. For any given country, this could be an important element in the assessment of the scope for diffusion and hence of the optimal choice of regulation to speed broadband diffusion.

In a nutshell, we follow the approach suggested by Bouckaert et al. (2010), but we narrow the sample to Europe, cover a somewhat longer time period and model the degree of competition by focusing on the market shares of the key forms of broadband delivery rather than on an Herfindhal index. This allows us to analyze the subject from a different perspective. Our main result is to show that updating the time period and modeling competition differently does not change the results found by earlier studies on more mature economies in general and on Europe in particular. For the most recent period for which data is available, intra-platform competition brought by service-based access is not an accelerating factor of broadband diffusion (or investment) – unlike competition brought by facility-based access.[5] Inter-platform competition continues to be key to broadband diffusion in Europe.

[4] In most countries, according to European Commission (2010) incumbents still control a large share of the market: Italy 57%; Spain 55%; Germany 46%; France 46%; Poland 40%.

[5] The main explanation for these empirical results is a trade-off between static and dynamic efficiency. Even though access regulation promotes competition in the short run on a retail level, it is likely to lower incentives to invest in infrastructures for incumbents forced to share their network and entrants free-riding on the incumbent network.

To explain how we get this result, the paper is organized as follows. Section 2 offers a brief reminder of the broadband technical aspects, both on technologies and access forms to explain our choice of variables. Section 3 discusses the model and the data. Section 4 presents the results. Section 5 concludes.

2. Technologies and access forms in Europe: a quick overview

The most common technology in Europe is the **xDSL (Digital Subscriber Line)** which represents about 79% of European fixed lines in 2010 (European Commission, 2010). It uses the telephone network which had to be upgraded to allow the transfer of information. Its main disadvantage is that it is a distance-sensitive technology. The quality of information transfer decreases as the distance between the end-user and the local exchange (DSLAM) increases. There are different DSL technologies, the key ones are HDSL, SDSL, ADSL (Asymmetric Digital Subscriber Line), RADSL and VDSL. They are distinguished by the symmetry (upstream and downstream), the speed and the maximum distance of the transmission.

A second well spread platform is **cable modem technology -** the main competitor of DSL which represents about 15% of European fixed lines (European Commission, 2010). It uses the TV cable networks that have been upgraded for the transmission of information both ways (upstream and downstream). There is no distance limitation with this technology. However, one of its drawback is that it is limited in the quantity of users sharing a same network (till the head end), the more users the lower the quality of information.

A third, and increasing popular, technology is the **FTTx (fiber to the location x)**, e.g. fiber to the home (FTTH), fiber to the building (FTTB), fiber to the curb (FTTC), etc. It consists in bringing the fiber a step closer to the end-user. The speed of transmission of this technology is much higher than for the other technologies and has no limitation of distance and quantity. However, deploying fiber implies tremendous investments.[6] Its expansion has been relatively high in some European countries including Denmark (over 10% of lines), Sweden and Slovakia (both over 20% of lines).

[6] According to the European Commission (2012), it could cost more than 200 billion EUR to bring high speed Internet to all Europeans in line with the agreed Digital Agenda targets.

Finally, there is the **fixed wireless broadband** which uses microwaves to transmit signals between hub sites and an end-user receiver. This technology might be used where it is too costly to develop underground infrastructure (e.g. mountainous regions). Its main disadvantage is that it is limited by a low rate of transmission.[7]

Because inter-platform competition may involve costly investments (and therefore low economies of scales) regulators force incumbent providers to unbundle their network at a regulated price. It gives the opportunity for entrants to retail the product by leasing the lines. This mandatory access can take different forms, below they are ranked from reselling the same service as the incumbent to the full local loop unbundling (LLU) needing more investment in equipment from the entrant:

- **Reselling**: the entrant supplies mostly the same service as the incumbent. This form of access does not need much investment from the alternative operator.
- **Bitstream access**: the entrant supplies its own product, however not much different from the service supplied by the incumbent. This form of access needs very little investment from the alternative operator.
- **Shared access**: lines are shared between entrants and incumbent but the latter keep on selling phone services while the entrant supplies the broadband service.
- **Full LLU:** when leasing the line, the entrant needs to upgrade the network. This form of access needs the most investment from the entrant.

In the empirical analysis, following Bouckaert et al. (2010), we simplify the menu of options and define two main groups of access. The first is the "**service-based access**" (reselling and bitstream access) needing less investment and implying less competition over price and quality of the product. The other one called "**facility-based access**" (shared and full LLU access) needing more investment which implies more competition over price and quality.

[7] There are other technologies such as satellite (about 0.3% of EU broadband offerings) and broadband power line (using the electric network and proved no to be profitable for operators) but these technologies play a minor role in Europe. Also there is the mobile broadband (e.g. 3G) but this empirical study will focus on fixed broadband in order to keep the analysis on a more homogeneous market.

3. The model and the data

To organize the discussion on the evidence on the most desirable option for Europe, we organize around three specific questions (Q) and try to provide answers based on an exclusively European dataset. These questions are as follows:

- *Q1: Do current approaches to allow access to the incumbent DSL network slow down broadband diffusion as suggested by some of the earlier research?*
- *Q2: Do all provision options to scale up broadband have comparable effects? (i.e. Does service-based access have a more negative[8] impact on diffusion than facility-based access?)*
- *Q3: Does the market share of the incumbent have an impact on broadband diffusion?*

To measure broadband diffusion (our dependent variable), we rely, as many others do, on the penetration rate of the fixed broadband (referred as Bd_pen). It represents the number of broadband lines for one hundred inhabitants. We use the data from the OECD broadband portal.[9]

A key element of the answer to these questions is our definition of the market we are looking at and the specific way we unbundle the market to model and monitor the relative importance of its key actors. We considered all broadband lines separated into four groups:

1. DSL lines supplied by the incumbent.
2. DSL lines supplied by entrants using service-based access (bitstream and resale).
3. DSL lines supplied by entrants using facility-based access (full LLU and shared).
4. Lines supplied by any operator using other technologies than DSL (cable, wireless, optical fibre,...).

Each of these four groups is given as a percentage of the whole broadband network. The sum of these variables is thus always equal to 100. We focus on the share of each segment of the market rather than the Herfindhal index often used by earlier researchers. We prefer this approach simply because when separating service-based and facility-based competition, it is problematic to compare the impact of one variable to the other. Indeed, it implies the computation of two different HHI variables which are based on the same market segment (i.e. the DSL market segment). For example, in Bouckaert

[8] Or less impact if both coefficients are positive.
[9] http://www.oecd.org/document/54/0,3746,en_2649_34225_38690102_1_1_1_1,00.html

et al. (2010) the sum of the market shares of operators competing on the facility-based segment is always 100%. Whereas the sum of market shares of operators competing on the service-based segment is not. It is 100% minus the market share of operators based on shared and full LLU access. In this case, the HHI would be based on different scales for the service-based competition and for the facility-based competition variables.

In order to compare the effects of service-based access, facility-based access and other technologies, we benchmark the analysis on the DSL lines supplied by the incumbent (i.e. the impact of the other sources of provision is normalized to this impact). More specifically, the key explanatory variables are thus the broadband percentage of the four groups - as cited above - minus the group represented by the incumbent:

- ***Service*** ($service_{i,t}$) is the percentage of service-based access lines. This part of the market corresponds to the DSL access needing the less investment from entrants.
- ***Facility*** ($facility_{i,t}$) is the percentage of facility-based access lines. This part of the market corresponds to the DSL access needing the most investment from entrants.
- ***Other*** ($other_{i,t}$) is the percentage of the total lines based on non-DSL technologies. Among these, the cable is the main competitor of the DSL but there is also the optical fiber that is getting more and more scope in Europe, the wireless and other less significant technologies.

This approach increases the transparency of the results in comparison to earlier studies in the sense that we take into account a new element, the market share of incumbent, thus bringing a new perspective on the impact of access regulation on broadband penetration (Q3). In particular, introducing variables in terms of percentage of the whole broadband network allows for an evaluation of the relative impact of the various DSL access forms on the diffusion simply by looking at the magnitude of the coefficients, specifying if DSL access forms are driving factors of broadband diffusion (Q1, Q2, and Q3). Adding two years of data (compared to the study of Bouckaert et al. (2010) or looking at more recent data on Europe than Distaso et al. (2007)) might lead to different conclusions knowing the high dynamics of this industry.

The data set for these variables comes from the “working document on broadband access in the EU: situation at 1 July 2008” for data from 2003 until 2008; from the “working document on broadband access in the EU: situation at 1 July 2009” for 2009; from the “15th Progress Report on the Single European electronic

Communication Market-2009[10]" for January 2010 and from the "CoCom Broadband lines July 2010 data exercise" for July 2010.

The control variables we consider follow the common practice in the literature and include the following:

- GSP (Real Gross State Product per capita (Euro)[11]),
- pop_dens (number of inhabitant per square kilometers), and
- pc_pen (number of households having at least one computer for 100 households).

In order to account for the non linearity of the time trend of the dependent variable, quadratics terms (trend and trendsq) have been introduced into the model.[12]

The specific model estimated is the following:

$$Bd\_pen_{i,t} = \beta 0 + \beta 1\ service_{i,t} + \beta 2\ facility_{i,t} + \beta 3\ other_{i,t} + \beta 4\ GSP_{i,t} + \beta 5\ pop\_dens_{i,t} + \beta 6\ pc\_pen_{i,t} + \beta 7\ trend_{i,t} + \beta 8\ trendsq_{i,t} + u_{i,t}$$

The estimation is based on data from 18 EU countries[13], from July 2003 until July 2010 at biannual observation frequency.[14] To ensure the robustness and consistency of the coefficients and avoid underestimations of their value, we rely on the Arellano (1987) specification with the White coefficient covariance estimates.

The model is thus very similar to the model suggested by Bouckaert et al. (2010). Four differences are worth noting, in addition to the timing of the sample coverage. First, we rely on fixed effects rather than random effects as they do. This is because we ran an Hausman test which validated the fixed effect approach for our panel. The fixed effect specification removes unobserved effects that are constant through time such as cost of developing infrastructure (e.g. different according to the geology of the country). The fixed effect specification has as drawback that it also removes observed effects that are

[10] http://ec.europa.eu/information_society/policy/ecomm/library/communications_reports/annualreports/15th/index_en.htm

[11] The monetary variables were deflated and converted into constant Euros of 2005.

[12] The control variables in Bouckaert et al. (2010) are: quadratic trends variables which reflect the general tendency in the dependent variable; the density of population; the population dispersion (percentage of population sharing 50 % of the country); the GSP per capita; the PC-penetration (number of households having at least one computer), the average price and speed of broadband connexion and a lagged dependent variable in a separate regression to consider the persistence of the broadband penetration rate through time.

[13] These countries are Germany, Austria, Belgium, Denmark, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Netherland, Poland, Portugal, Czech Republic, United Kingdom and Sweden.

[14] Except for population density and PC-penetration which are based on annual frequency.

relatively constant through time. As a result, some coefficients lose significance, e.g. population density. The second is that we do not share the same proxy for the explanatory variables - as long debated here above. The third is that we do not have a price variable as they do. This is because we did not find good proxies[15] to use to match our categorization of the market.[16] The fourth difference is that we do not discuss the results of the model with a lagged dependent variable.[17]

A final technical comment is in order. It concerns the risks of endogeneity. Probably, because of the relatively low number of observations and the high loss in degree of freedom when using the necessary instrumental variables, the test could not be run.[18] If endogeneity is a problem, we may be under- or overestimating some of the coefficients of endogenous variables. Indeed one may envisage a high (low) penetration rate could be the cause of policies that are less (more) restrictive towards the incumbent which would result in a decrease (increase) of the service-based and facility-based access. This possibility is even more likely to happen if regulatory authorities base their politics on the ladder of investment theory.[19]

In order to attempt to mitigate the risk of endogeneity, we estimated our model using predetermined regressors. As can be seen in the Appendix, the order of magnitude and statistical levels of significance of the estimated coefficients associated with these variables are not substantially altered and thus validate to the findings reported in the next section in Table 2. Note that the fixed effect specification, which removes some unobserved effect from residuals, also helps reducing endogeneity.

To conclude the discussion on data, Table 1 summarizes the evolution of the values for the key variables during our period of analysis. It shows that during the period

[15]Price is uneasy to estimate because of bundle offers (telephony, internet and television) and because price has to be associated to quality which is also a difficult variable to estimate.

[16] The differences in results with the study of Bouckaert et al. (2010) are due to the difference in the variables rather than the two more years of observations. Indeed, we tested our model on the data from 2003 until 2008 to match the timing of their panel and the conclusions we discuss later are not significantly impacted.

[17] Although we estimated the model with a lagged dependent variable and we reach a result similar to the one found by Bouckaert et al. (2010), we decided not to use it. Indeed, unsurprisingly, the lagged variable dominates the results, confirming Achen (2000) ("lagged variables can artificially dominate the regression whether it has a great deal of explanatory power, a little, or none at all").

[18] We implemented GMM-SYS estimators (Blundell and Bond, 1998) and experimented various sets of instruments based on past values of explanatory variables as well as a specification including a lagged dependent variable. In all cases, Sargan and Hansen of over-identification tests were inconclusive.

[19] Endogeneity is strongly argued by Grajek and Röller (2011) which focuses on investment rather than penetration rates and relied on a variable measuring the intensity of regulation to measure the impact of government intervention. In their model, with their variables, they find that it is a problem.

under scrutiny, the broadband penetration rate has been multiplied by a factor of about six. The rest of the table shows the evolution of the relative market shares of the various forms of provision of broadband services. It shows that the share of service-based access has somewhat dropped while the share of facility-based access has increased significantly. The market share of the incumbents in Europe has hardly diminished. Non-DSL technologies saw a market share equivalent to that of the incumbents in 2003 to less than a third of the market.

Table 1: Statistics summary. European average (EU 18)

	July 2003	**July 2010**	**Average value 2003-2010**
Broadband penetration rate	4.17	24.41	15.60
Composition of broad provision (%)	100	100	100
Service-based access	8.18	6.98	10.07
Facility-based access	4.63	16.63	11.11
Market share of the incumbent	44.30	43.81	48.12
Non-DSL technologies	**42.90**	**32.55**	**30.68**

Source: Working document on broadband access in the EU: situation at 1 July 2008, working document on broadband access in the EU: situation at 1 July 2009, 15th Progress Report on the Single European electronic Communication Market-2009, CoCom Broadband lines July 2010 data exercise, Eurostat and OECD broadband portal.

4. The results

The key results from the fixed effect model are reported in Table 2. Before discussing the key variables, it may be useful to comment briefly on the control variables. We find, as the authors before us did, that the GSP per capita and the population density have a positive impact on broadband diffusion.[20] It is a fairly reasonable result as a higher GSP will result in a higher demand for broadband and a higher density of population will reduce the cost of expanding the broadband network. It is somewhat surprising that we do not find a statistically significant coefficient for the PC-penetration. Finally, the quadratic terms for trend indicate that broadband penetration increases through time but at a decreasing rate. Indeed, the trend variable has a positive coefficient and the square of the trend has a negative coefficient.

[20] Because the density of the population and GSP are rather constant through time and may be very different from one country to another, it may rather be interpret from a random effect regression.

Moving on to the key variables of interest and to the three core questions raised earlier, the results provide some useful insights. First, the coefficient of two out of three explanatory variables is significantly positive. The only one not to be significant is for *service*. This suggests that the incumbent market share (the fourth mode of provision in our categorization which defines the benchmark to which the other provision forms are compared) drives the broadband diffusion less than the *facility* and *other* variables. In other words, the bigger the incumbent market share as compared to these two variables, the slower the broadband diffusion has been in the recent period in Europe. Moreover, stimulating service-based access did not help during the period under investigation.[21]

Second, the results suggest also that in Europe, the facility-based access has been more conductive of broadband diffusion than the service-based access. This is consistent with the results found by Bouckaert et al. (2010) for the OECD, but in contrast to Gruber and Koutroumpis (2011) for a worldwide sample.

Third, the importance of non-DSL technologies as a source of improvements in broadband penetration in the recent European context is also validated by the results. This confirms the earlier results by Bouckaert et al. (2010); Denni and Gruber (2005) and Grajek and Röller (2011). They had all already highlighted the important impact of non-DSL technologies on the fixed broadband penetration rate.

Finally, there is also a major lesson to be learned from the size of the coefficients. Table 2 shows that the coefficient of the variable ***other*** is in the same order of magnitude as *facility*. These regressors turn around 0.1 which means an increase of 10 percentage point of the share of *other* or *service* in the market was associated with an increase in the penetration rate of 1 percentage point during that period in Europe.

It is interesting to note that in spite of that similarity in effectiveness in terms of broadband penetration increases, policies and preferences have led the market shares of these two forms of provision to evolve in opposite directions. Table 1 showed that the market share of facility-based access increased from 4.63 in 2003 to 16.63 in 2010. In contrast, the market share of non-DSL technologies dropped from 42.9% to 32.55%. However, accounting for the relative lower effectiveness of incumbent based access, the very slow drop in their market share, from 44.30 to 43.81 should be a matter for concern.

[21] In order to confirm this assumption, other regression (including the incumbent market share and excluding another explanatory variable) were estimated, they all lead to the conclusion of a negative impact of the incumbent market share on the penetration rate.

A “laissez faire” or business as usual policy does not seem to be the right option in the European context based on the recent experience as letting a powerful incumbent manage the market in its best interest may slow down broadband diffusion.

Table 2: Determinants of broadband penetration rate *Bd_pen*

	Fixed effect regression Coefficient (Standard error)
Service-based access *Service*	-0.0187 (0.0576)
Facility-based access *Facility*	0.0969* (0.0553)
Non-DSL technologies *Other*	0.1037*** (0.0275)
GSP per capita *GSP*	0.0012*** (0.0007)
Population density *Pop_dens*	0.2000 (0.2092)
PC penetration rate *Pen_pc*	-0.1749 (0.1227)
Time trend *Trend*	2.82*** (0.5332)
Square of the time trend *Trendsq*	-0.0667*** (0.0180)
R^2	0.9246
Hausman test : Chi-Sq. Statistic (prob)	39.89 (0.0000)
Number of observations	270 (15 periods X 18 countries)

Note: significance levels are indicated with ***, **, *, respectively 1%, 5% and 10%.

Given the low impact of service-based access, the drop in its market share from 8.18% to 6.98% should not be an issue. There is a lesson to be learned however from this drop. Since service-based access has a lower impact on the broadband penetration rate than the facility-based access, and than the non-DSL technologies, policies encouraging the bitstream access and the resale do not seem to be good options for Europe, based on the most recent experience. Continuing to bet on facility-based access and inter-platform competition seem to be the most desirable solutions for now in Europe.

5. Concluding comments

Although the paper provides new insights focused on Europe, it has its limitations which define a further research agenda. From a policy viewpoint, the main limitation of the paper is that it could not be designed to pick up the recent increase in penetration of

mobile broadband among consumers. This technology may indeed be slowly becoming a substitute to fixed broadband for users[22]. From a modeling perspective, the difficulties we encountered in testing carefully for endogeneity and in including a price variable and maybe a quality variable such as transmission speed, may lead some to question the results. We feel however that as they stand, they are robust enough to provide the following diagnostic of the recent European experience in trying to answer the main question raised by the paper: i.e. *how effective were Europe's regulatory choices in promoting broadband penetration during most of the 2000s.* Our answer is that while access regulation helped, not all forms of access regulation worked as effectively as the regulators may have hoped for to promote broadband penetration in Europe.

The idea to bet on service-based regulation to minimize the regulatory demands has not been a good one so far in the EU context. Since service-based access needs little investment from entrants, it does not raise the same type of regulatory concerns as the regulation of facility-based access. However, the evidence suggests that the former did not have a significant impact on broadband penetration either.

Although facility-based access needs more investment in equipments from the entrants and may demand a more complex supervision of competition on price and quality, it seems to have had a higher broadband penetration payoff in Europe. For now, based on the recent experience, an ex-ante regulation focusing on this access form seems to continue to be appropriate in order to promote broadband diffusion.

The real regulatory challenge for Europe (and many other regions of the world), is to manage to ensure that incumbents have a better incentive to invest. The current regulatory environment has not been as effective as it could have been in getting incumbents to invest and play the competition game in the interest of users.

The failures of service-based access and the insufficient effectiveness of incumbents has somewhat been compensated by the development of non-DSL technologies such as the cable, the optical fiber and the wireless. Continuing to bet on these innovations seems to be a good strategy to promote longer run competition in the sector as well as to speed up broadband penetration.

[22] For example, in the EC 14th Report on the Implementation of the Telecommunications Regulatory Package (2008), the decrease in fixed broadband penetration in Finland is said to be explained by a fixed-to-mobile substitution.

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Appendix: Determinants of broadband penetration rate Bd_pen_t

Fixed effect regression with predetermined regressors Coefficient (Standard error)	
Service-based access *Service* $_{t-1}$	0.0316 (0.0302)
Facility-based access *Facility* $_{t-1}$	0.1467*** (0.0298)
Non-DSL technologies *Other* $_{t-1}$	0.0880*** (0.0180)
GSP per capita *GSP*	0.0015*** (0.0003)
Population density *Pop_dens*	0.0188 (0.0066)
PC penetration rate *Pen_pc* $_{t-1}$	-0.0047 (0.0397)
Time trend *Trend*	2.63*** (0.2096)
Square of the time trend *Trendsq*	-0.0709*** (0.0103)
R^2	0.9232
Hausman test : Chi-Sq. Statistic (prob)	34.45 (0.0000)
Number of observations	270 (15 periods X 18 countries)

Note: significance levels are indicated with ***, **, *, respectively 1%, 5% and 10%.