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The impact of intra-platform competition on broadband penetration[☆]

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ABSTRACT

There has been an extensive debate about the role of broadband access regulation on market outcomes. This paper estimates the impact that the different modes of competition have had on broadband take-up to date, using a data set for EU27 countries. We find that ULL, which is one of main types of access-based competition in Europe, has had a positive impact on broadband take-up. However, the impact of ULL becomes smaller as its share increases. That is, ULL entry is less effective in areas where ULL take up is already high. Further, there is evidence of a crowding out effect between ULL and inter-platform competition. This means that ULL is less effective in enhancing broadband penetration in the areas where alternative networks already have a significant share of broadband lines.

1. Introduction

Operators around the world are deploying new fibre networks (next generation access networks or NGAs) in order to offer very high-speed broadband services. There has been much debate about the role that governments and regulators should play in helping to encourage the deployment these new networks and encourage the adoption of ultra-fast broadband services. A key question is whether access based obligations over copper networks should be extended to fibre infrastructures. The main argument in favour of access regulation is that it makes new entry easier, as the entrant has to build only part of a network, or no network at all. This potentially allows for more intense competition if there is a greater number of market players. However, there is a concern that mandating access could deter operators' from investing in fibre networks in the first place if the operators think that they will struggle to make a return on their original investment.

In most countries, access regulation for copper networks has been in place for a number of years, being introduced in the early 2000s in Western Europe. Entry into broadband markets can take a number of forms. New entrants can make use of the incumbent's network, which is known as intra-platform competition. Alternatively, entrants can completely bypass the incumbent's network, using an alternative technology, such as cable broadband. This is known as inter-platform competition. There are different levels of intra-platform competition ranging from resale of the incumbent's products to full unbundling of the local loop (ULL). Resale requires a much smaller upfront cost to the new entrant compared to ULL, but it also offers much less scope for product differentiation. Another form of access, which sits in between ULL and resale, is bitstream. The figure below summarises the

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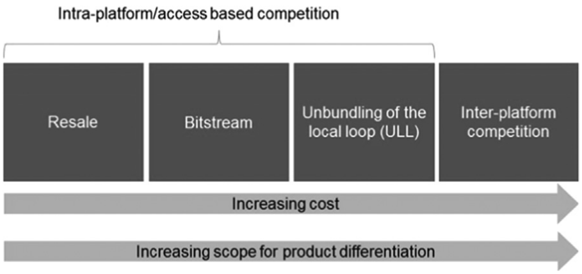

Fig. 1. Different forms of competition in broadband markets.

different forms of broadband competition (Fig. 1).

Europe is considered to have placed most emphasis on a wholesale broadband access regime. Regulators have relied heavily on wholesale access regulation to promote competition and investment in fixed broadband markets. Although the experience varies across countries, the take-up of the incumbent's regulated wholesale services has been relatively high. As of January 2012, 45.3% of broadband DSL lines at EU level were provided by new entrants.[1] Among these, 98.8% relied on incumbents' wholesale products, rather than entrants own DSL network. The most popular wholesale product has been full ULL.

The popularity of ULL can be explained by the regulatory approach adopted by most jurisdictions in Europe. ULL prices have been set based on costs, which has led to a significant fall in ULL prices over time. Between October 2005 and October 2011 the monthly average total cost of full ULL has decreased from 12.4 to 9.7 euro. For shared ULL access monthly prices decreased from 5.1 to 2.9 euro in the same period. In contrast, in many EU countries, bitstream prices, at least initially, have been set on a retail minus basis, which makes it difficult for bitstream providers to compete on price. As we will explain below, the difference in the approach that regulators have taken to ULL and bitstream may help explain the results obtained in our analysis.

Given the current debate about the appropriate form of access regulation for fibre networks, this provides an apt time to review the effectiveness of access regulation for copper networks. This paper adds to this debate by looking at the impact of wholesale broadband policies on broadband take-up, using the latest available data set for the EU27.

There are several reasons why we have focused on EU27 countries.

- There is sufficient variation in the take-up of wholesale broadband access products within the EU27 to be able to make inferences on how intra-platform competition affects broadband outcomes. As such, whereas in Bulgaria, Lithuania, Malta and Romania the percentage of ULL and bitstream (plus resale) lines was close to 0% in 2011, in France and Greece this percentage was 50% in the same year.
- At the same time, the drivers of broadband take-up will to some extent be similar, which makes it easier to identify the impact of the different measures of intra-platform competition.
- There is good quality data available. The EC provides information on the number of DSL ULL, bitstream and resale lines for EU27 countries for an extensive period (2004–2011) on a bi-annual basis. This information is not easily available for non-EU countries. Even if we focus on OECD countries: (i) the number of ULL lines is not available for some of the non-EU countries, e.g. Japan; and, (ii) ULL lines include also non-DSL lines.

Our paper is unique in that it considers whether the different modes of competition are subject to diminishing returns (not necessarily over time). It also considers whether intra-platform competition is less effective when there is already high inter-platform competition.

There is an extensive empirical literature addressing the impact of the different modes of competition on broadband outcomes. However, existing articles: (i) either focus on a given mode of competition[2]; (ii) or consider heterogeneous, not comparable, measures for inter- and intra-platform competition[3]; (iii) and do not address the existence of diminishing returns or the interaction between the different modes of competition. The exception would be Nardotto, Valletti and Verboven (2015), who report a decreasing impact for ULL over time.

Next section provides a more detailed review of existing literature. The approach is set out in Section 3. The results are included in Section 4. Section 5 concludes and discusses the policy implications. In an Appendix we include further details of the data that we have used and some further tests.

2. Literature review

There is a wide empirical literature investigating how access regulation affects broadband diffusion. Studies have either been carried out across countries or within-countries for countries where there is regional variation in the mode of competition (like the

[1] See ⟨https://ec.europa.eu/digital-agenda/en/download-data⟩

[2] For example, Crandall, Eisenach and Ingraham (2013) focus on the role of intra-platform competition and do not control for inter-platform competition.

[3] For example, Höffler (2007) use the ULL price in order to assess the impact of ULL and the market share of cable to estimate the impact of cable on broadband penetration.

US case).

The literature initially focused on the US given its early adoption of an ULL policy. The studies considered the implications of access based regulation on investment and broadband penetration. On the latter, Aron and Burnstein (2003) explore the impact of inter-platform competition on broadband adoption using cross-sectional data at state level around 2000.[4] They find a substantial and statistically significant positive impact on broadband adoption from inter-modal competition. Latter, Denni and Gruber (2007) find a similar result using a panel data set for US states for the period 1999–2005. Neither of them considers a direct measure of intra-platform competition.[5]

A recent paper by Nardotto et al. (2015) uses regional data in the UK to analyse the impact of ULL on broadband adoption and quality (in terms of speed). They find that a positive impact from inter-platform competition on local broadband penetration and a declining impact over time from ULL (which ultimately becomes negative). They also find that the local exchanges that experienced ULL entry have a higher average broadband speed than local exchanges without ULL entry.

As data has become available, a number of studies have emerged evaluating access policies in Europe. This includes Cincera, Estache and Lauriane (2012), which considers a panel data with 18 EU countries in the period 2003–2010; Bouckaert, van Dijk and Verboven (2010), which uses data from 20 OECD European countries in the period 2003–2008; and, Höffler (2007) who looks at 16 Western European countries in the period 2000–2004. Other recent papers consider an even wider set of countries. For example, Crandall et al. (2013) use a sample of 28 OECD countries in the period 2001–2010, while Gruber and Koutroumpis (2012) rely on data from 167 countries over the period 2000–2010.

The results from this literature are mixed. Cincera et al. (2012) and Gruber and Koutroumpis (2012) find that intra-platform competition in the form of ULL encourages broadband adoption. In contrast, Bouckaert et al. (2010), Höffler (2007) and Crandall et al. (2013) find no positive effect from intra-platform competition on broadband penetration.

The differences arise either due to the different data sets used (as the sample period and countries consider differ depending on the paper) or due to the specification of the model and, particularly, the way in which intra-platform competition is modelled. Crandall et al. (2013) control for intra-platform competition using the number of years since ULL was introduced. In contrast, Bouckaert et al. (2010) use the concentration indices for the different modes of competition. Also, the measure of broadband penetration differs across studies, with some considering penetration over inhabitants,[6] others over telephone lines,[7] and others over the number of households.[8]

In this paper, we use data from January 2004 to July 2011, which is a longer time period than most existing studies have used. Using a long time period is useful because it allows us to consider dynamic issues, such as diminishing returns effects, and even test whether the impact of intra-platform competition depends on the stage of broadband diffusion (Cincera et al., 2012 suggest that the impact of the factors affecting broadband penetration may depend on the actual broadband uptake[9]).

As in the case of Bouckaert et al. (2010) and Höffler (2003), we consider broadband penetration over the number of households. We consider this to be a better measure than the number of broadband lines over total population in a country. Everything else equal, population penetration will be smaller in countries with higher household size. This is because the decision to acquire a broadband connection is usually taken at household level, sharing the broadband line between the members of the household. By using broadband penetration at household level, we are implicitly taking into account the potential differences in household size across countries.

We control for intra-platform competition using the actual uptake of the different modes of competition, including resale, bitstream and ULL. This allows us to measure for example, what impact a 10% increase in the share of ULL lines has on broadband take-up. It is not possible to draw such conclusions when intra-platform competition is controlled for by using dummy variables (for example, whether ULL has been introduced or not),[10] or using the number of years since the obligation was imposed.[11]

In contrast to our specification:

- Some papers consider measures of inter- and intra-platform competition which are not directly comparable. For example, estimating the impact of ULL using the ULL price, whilst using the market share of cable operators to assess the impact of inter-platform competition.[12]
- Not all the articles consider both inter- and intra-platform competition. For example, Crandall et al. (2013) do not consider inter-platform competition in their analysis. And,
- None of the contributions consider the possibility of a crowding out effect between intra- and inter-platform competition and only Nardotto et al. (2015) assess the presence of diminishing returns, but only for ULL and over time.

[4] Some variables refer to other years, e.g., the regulated price of the local loop taken as of May 2001.
[5] Aron and Burnstein (2003) control for the regulated price for a Regional Bell Operating Carrier (RBOC) unbundled network element (UNE) loop in Zone 1 (urban areas) in the state, as of May 2001- Denni and Gruber (2007) consider a measure of competition which also includes CLECs owned lines, hence, mixing intra and inter-platform competition.
[6] For example, Cincera et al. (2012), Crandall et al. (2013), Denni and Gruber (2007) and Aron and Burnstein (2003).
[7] Nardotto et al. (2015).
[8] Bouckaert et al. (2010) and Höffler (2007).
[9] See Cincera et al. (2012), footnote 3.
[10] Nardotto et al. (2015) consider a dummy variable which is equal to one if investments have been made to enable ULL in the local exchange.
[11] This is for example the approach followed by Crandall et al. (2013).
[12] For example, Höffler (2007).

Our specification and findings are closest to Cincera et al. (2012), who also exploit a panel data set of EU countries. However, their analysis excludes Bulgaria, Cyprus, Estonia, Lithuania, Luxembourg, Latvia, Malta, Romania, Slovenia and Slovakia, all of which are included in our analysis. Their measure of broadband penetration is relative to the population instead of over the number of households and they do not properly account for the endogeneity of the macroeconomic variables.

As in the case of Cincera et al. (2012), we find that both ULL and inter-platform competition exert a positive and significant impact on broadband penetration. Our results are robust to a large number of specifications and consistent with the findings of Calzada and Martínez (2013). The latter assess the impact of ULL on broadband prices. They find that broadband prices are lower in countries where entrants rely more on ULL, which may explain the positive impact on penetration associated to this mode of entry.

We further find that there are diminishing returns to both ULL and inter-platform competition and crowding out effects between the two modes of entry.

The next section describes our approach in more detail.

3. Data and approach

We estimate the impact of access-based regulation on broadband take-up. We build on the existing literature that was discussed in the previous section, by dealing with some of the issues identified and using an up-to-date data set. In addition, we also consider a number of novel questions which have not been addressed by existing papers. We consider whether the impact of ULL and inter-platform competition are affected by a number of factors, such as diminishing returns, and the stage of broadband diffusion. We also look at whether the impact of access regulation depends on the level of inter-platform competition.

Our empirical analysis relies on the use of a panel data set, including 27 EU countries in the period January 2004- July 2011. For each country and semester, the European Commission (EC) publishes information on: (i) the total number of broadband lines; (ii) the number of bitstream accesses; (iii) the number of ULL broadband lines; (iv) the number of broadband lines from alternative platforms; and, (v) the number of broadband resale lines. We have also collected data on other potential drivers of broadband take-up, such as GDP p.c., the level of education and population density. A table in the Appendix presents summary statistics of the variables considered.

Our basic specification is as follows:

$$Takeup_{it} = Constant + \beta_1 Inter-platform_{it} + \beta_2 ULL_{it} + \beta_3 Bitstream_{it} + \beta_4 Resale + \beta_5 Time_t + \sum \beta_j Socioeconomic_{it} + Error_{it}$$

where:

$\boldsymbol{Takeup_{it}}$ is the percentage of broadband lines over the number of households in country i and time t.

$\boldsymbol{Interplatform_{it}}$ is the percentage of new entrants non-DSL lines in country i and time t.

$\boldsymbol{ULL_{it}}$ is the percentage of ULL lines over the total number of broadband lines in country i and time t.

$\mathbf{Bitstream_{it}}$ is the percentage of bitstream lines over the total number of broadband lines in country i and time t.

$\mathbf{Resale_{it}}$ is the percentage of resale lines over the total number of broadband lines in country i and time t.

Note that the variables *intraplatform, ULL, Bitstream* and *Resale* are not an identity as we are not including the incumbent's share of lines.

$\boldsymbol{Time_t}$ is a linear time trend.

$\boldsymbol{Socioeconomic_{it}}$ is a set of socioeconomic variables which are relevant for broadband penetration. These include, ***GDP per capita***, adjusted for PPP, ***population density*** and an ***educational variable*** (the percentage of 25–34 year olds with tertiary education).

$\boldsymbol{Error_{it}}$ is an error term.

In contrast to some of the existing papers, we measure take-up as the percentage of households that have a fixed broadband connection. As already discussed, this is a potential improvement on much of the literature, which typically measures broadband penetration on a population basis.

We consider direct measures of intra-platform competition, instead of relying on dummy variables which may not fully reflect the intensity of regulation on the different forms of intra-platform competition. For example, a dummy variable for ULL or the number of years since unbundling policies were introduced,[13] does not measure the strength of the regulatory approach towards ULL. Further, we distinguish between the different forms of intra-platform competition (ULL, bitstream and resale). Few studies use both the actual uptake and also make the distinction between the different types of intra-platform competition.[14]

We also control for inter-platform competition, which not all of the existing literature does.[15] Therefore, we are considering what impact the different measures of intra-platform competition have for a given level of inter-platform competition. We measure inter-platform competition, as the percentage of non-DSL lines operated by new entrants.

As well as controlling for the different forms of competition, we also control for a number of socio-economic factors. There are likely to be several demand- and supply-side drivers of broadband take-up. On the demand-side, GDP per capita and education are potential drivers. Countries with higher GDP per capita are likely to have higher take-up as, all else equal, broadband will be more affordable. Countries with a high level of education may also have greater demand for broadband, as the population may derive

[13] As Crandall et al. (2013) do.

[14] For example, Cincera et al. (2012) and Bouckaert et al. (2010).

[15] Crandall et al. (2013).

greater benefits from internet usage and may have been more exposed to internet usage during their studies. On the supply-side, population density may well be important, as it is likely to influence the cost of rolling-out a network. Countries with higher population densities may have lower network roll-out costs per person, as a smaller network will be required, all else equal. Therefore, population density is likely to have a positive impact on broadband take-up.

Broadband take-up follows a strong time trend. Even if other explanatory variables had remained unchanged over the period under consideration, it is likely that take-up would have increased due to technological improvements. Therefore, it is important to control for time in our model. We consider two options: (i) including a time trend; and, (ii) control for time fixed effects.

Broadband prices are likely to be a key determinant of broadband take up. One would expect a negative relationship between broadband penetration and prices (everything else the same). Measuring broadband prices is a challenging task as there tends to be many different broadband tariffs within a given country. There is a lack of good quality data available on the uptake of the different tariffs. This makes it difficult to calculate a weighted average price within a given country. Some organisations, such as the OECD, have calculated an overall price for a country by taking the minimum or median price for different speed baskets. This is not ideal, since this price may not reflect the price being paid by most consumers. A further complication with calculating an overall price is that many broadband packages form part of a bundle that also includes voice services and/or TV. Given the difficulties with measuring broadband prices, we have not included a price variable in our estimation.

As with prices, broadband quality is another factor which is likely to influence broadband take up. However, the best available data set on speed (provided by Ookla[16]), is only available from 2008 onwards. This would significantly reduce our sample size, so we have not included it.

3.1. Econometric approach

Our starting approach is using OLS with clustered standard errors (we will refer to this as our ‘basic specification’).[17] We also estimate our model using both fixed effects and random effects (the results from the later model are not reported in the paper). Fixed effects (FE) models are often used, as they control for country-specific factors which do not change over time. Comparing the fixed and random effects estimations, the Hausman test suggests that there are country fixed invariant effects in our data (see Table A4).

The main concern with using fixed effects is that it only exploits the within country variation, which means that it may not properly identify the coefficients of variables which do not vary significantly over time. This is, for example, the case of inter-platform competition, education and population density. This can be seen in the chart below (Fig. 2), which shows the coefficient of variation[18] both within and between countries.

To deal with the potential country fixed specific effects, without relying exclusively on the within country variation (as implied by the fixed effects estimation), we have grouped countries in 4 different regions following the UN classification of European countries.[19]

As the total number of fixed broadband lines is used to calculate both broadband take-up, as well as our different measures of competition, we have checked that our regressions do not suffer from a simultaneity problem, by lagging our measures of competition in the regression. These values will be pre-determined and therefore should not suffer from simultaneity. The results (not reported in this paper) show no material differences between the coefficients on the lagged values and the coefficients on the current values.

The socioeconomic variables may not be strictly exogenous. For example, broadband penetration has been found to exert a positive and significant impact over GDP p.c.[20] This creates a problem of reverse causality.

We have checked the potential endogeneity of the variables education and income by running the Durbin, Wu-Hausman and robust regression-based tests, after performing the instrumental variable regression.[21] Our results are also confirmed via the control function approach.[22]

The analysis reveals that while one cannot reject the hypothesis of exogeneity for the education variable, the income variable seems to be endogenous. Thus, we also control for the potential endogeneity of the income variable by using the lagged values of GDP p.c. and education as instruments for the current level of GDP p.c.

Our dependent variable, broadband penetration, is likely to present path dependence as broadband adoption has increased gradually over time in every country. Therefore, broadband penetration at time t-1 is likely to be a key determinant of broadband penetration at time t.

In order to account for the dynamic nature of broadband penetration, we run a system GMM model controlling for the

16 ⟨http://www.netindex.com/⟩.

17 We have also tried using bootstrapped clustered standard errors for our main specification. We have used 1500 replications. Our main results do not change when using bootstrapped clustered standard errors.

18 Ratio of the standard deviation to the mean.

19 See ⟨http://unstats.un.org/unsd/methods/m49/m49regin.htm⟩

20 See ⟨http://broadbandtoolkit.org/1.3⟩

21 Whereas both the Durbin and Wu–Hausman tests assume i.i.d error terms, the regression-based test of exogeneity tolerates heteroskedasticity, autocorrelated errors and clustering.

22 This method implies estimating a first-stage regression of the endogenous current level of GDP per capita on the exogenous explanatory variables of our model and the instruments (i. e. the lagged values of GDP per capita and education). By adding the residuals of the first-stage regression as a new dependent variable in the regression, we are able to control for the part of the error term that is correlated with the endogenous regressor. Hence, the remaining error term is thus uncorrelated with the GDP p.c. variable.

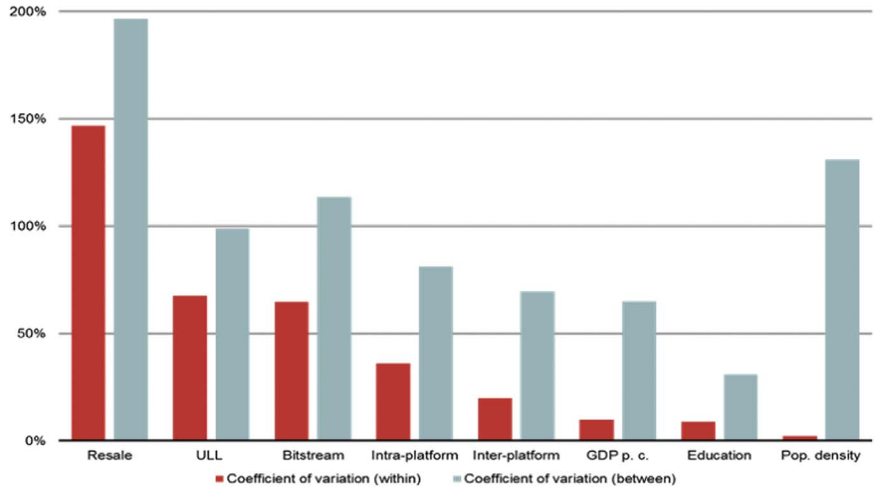

Fig. 2. Coefficient of variation between and within countries.
Source: author's calculations based on data from the European Commission, Eurostat and the World Bank.

endogeneity of GDP p.c. and restricting the instrument set to lags 3 and deeper.

4. Results

The table below summarizes the results for the different specifications we have considered. The first column ((1) OLS) reports the results under the basic specification. The coefficient for ULL implies that a 10% point increase in ULL increases broadband take-up by 3.2% points. The coefficient on inter-platform competition is slightly smaller than the coefficient on ULL. However, this difference is not statistically significant (Table 1).

The coefficient on ULL is robust. The coefficient is always significant and the estimated impact is in the range [0.323, 0.480] .[23] In contrast, the coefficient for inter-platform competition loses its significance in the specifications that control for country fixed effects, i.e., in specifications (2) FE and (5) TW-FE. This is likely due to the lack of sufficient variation of inter-platform competition over time, as commented above.

Hence, the coefficients under the fixed effects estimator ((2) FE and (5) TW-FE) need to be interpreted very cautiously for the variables that show a small coefficient of variation, such as: population density, education, GDP p.c. or inter-platform competition.

Instead, bitstream and resale seem to exert a negative or no impact on broadband penetration, with the coefficients being more volatile.

All of the other coefficients have the expected signs. The time trend, GDP per capita, population density and education all have a positive impact on take-up.[24] The high R-squared of the different specifications indicates that our model is explaining the majority of the variation in take-up.

Estimations (4), (5) and (6) control for the potential endogeneity of the income variable (GDP p.c.)[25] We use the lagged values of GDP p.c. and education as instruments for the current level of GDP p.c.[26]

Estimation (5), in addition, considers time and country fixed effects, via the two-way fixed effects estimator.[27] Whilst the last column shows the results taking into account that the dependent variable, broadband penetration, is likely to present path dependence.

Below we report some additional robustness checks we have undertaken.

4.1. Additional robustness checks

We have considered a number of additional robustness checks that are not presented in the paper. Given that broadband take-up follows a strong time trend, we tried allowing for more sophisticated time effects. When we included a quadratic time trend in specification (1), as well as a linear time trend, the coefficient on ULL fell very slightly to 0.31. We also included two lags of ULL. The sum of the coefficients on the current value of ULL and the two lags of ULL were 0.38. This is similar to the coefficient of 0.32 that we found in our basic specification.

[23] We also considered a specification including ULL prices, but this had minimal impact on the magnitude of the co-efficient on ULL (falling to 0.296).

[24] In the case of fixed effects, models (2) and (5), education loses significance probably due to the lack of significant variation over time.

[25] For example, broadband penetration has been found to exert a positive and significant impact over GDP p.c. See ⟨http://broadbandtoolkit.org/1.3⟩

[26] GDP is potentially endogenous if cyclical movements in GDP respond to short run variations in broadband take up. Lagged GDP is less likely to be correlated with these short run variations and lagged education controls for any possible longer run effects.

[27] Under some assumptions, the two-way fixed effects method may be equivalent to the difference-in-difference approach. The latter being unfeasible in this context given that ULL was present, with exceptions, in most of the countries of our sample in the period considered.

Table 1
Main results.

Variable	(1) OLS	(2) FE	(3) OLS-Regional	(4) IV	(5) TW-FE	(6) System-GMM[a]
Broadband penetration first-order lag						0.880***
						(0.030)
Inter-platform share	0.209**	−0.005	0.157***	0.166***	−0.022	0.028**
	(0.083)	(0.103)	(0.0557)	(0.058)	(0.103)	(0.013)
Intra-platform competition						
ULL	0.324***	0.370***	0.354***	0.357***	0.323**	0.057**
	(0.106)	(0.106)	(0.101)	(0.106)	(0.136)	(0.026)
Bitstream	−0.284	0.085	−0.294	−0.404**	−0.071	−0.059
	(0.196)	(0.154)	(0.195)	(0.200)	(0.150)	(0.038)
Resale	−0.273**	0.075	−0.420***	−0.473***	−0.027	−0.051*
	(0.111)	(0.175)	(0.093)	(0.096)	(0.161)	(0.030)
Log(GDP p.c.)	0.141***	0.152***	0.153***	0.168***	0.234***	0.024***
	(0.030)	(0.047)	(0.029)	(0.029)	(0.091)	(0.006)
Population density	0.000***	0.006**	0.000***	0.000***	0.006***	0.000***
	(0.000)	(0.002)	(0.000)	(0.000)	(0.002)	(0.000)
Education	0.005***	0.002	0.003***	0.003***	0.002	0.001***
	(0.001)	(0.003)	(0.001)	(0.001)	(0.003)	(0.000)
Time trend	0.029***	0.029***	0.029***			
	(0.001)	(0.003)	(0.002)			
Northern Europe dummy			0.107**	0.111***		0.016**
			(0.039)	(0.039)		(0.007)
Eastern Europe dummy			0.029	0.032		0.013
			(0.043)	(0.043)		(0.008)
Southern Europe dummy			−0.008	0.012		0.003
			(0.028)	(0.027)		(0.004)
GDP p.c. instrumented				Yes	Yes	Yes
Time dummies				Yes	Yes	Yes
Constant	−1.473***	−2.587***	−1.566***	−1.670***	−2.840***	−0.224***
	(0.291)	(0.617)	(0.298)	(0.298)	(0.956)	(0.063)
Number of observations	356	356	356	335	335	331
R^2	0.861	0.926	0.889	0.886	0.957	

Note: *, **,*** denote significance at 10%, 5% and 1% respectively. Robust standard errors in parentheses.
[a] In the system GMM model, the long-run impact of an independent regressor on the dependent variable is given by the coefficient of that regressor divided by the rate of adjustment between the short-run and the long-run periods, i.e. 1 minus the coefficient of the lagged dependent variable.

We also did an initial analysis of the drivers of ULL take-up, by collecting data on ULL prices. Both scatter plots and econometric analysis suggested that lower ULL prices lead to higher ULL take-up in Western European countries. However, in Central and Eastern European countries there was no obvious relationship between ULL take-up and ULL prices, which suggests that there are other factors that are more important in determining the take-up of ULL.

Overall, the coefficient for ULL looks quite robust. The coefficient of inter-platform competition is more volatile, losing its significance under the fixed effects specification due to the lack of sufficient within country variation. Our results are consistent with Cincera et al. (2012), who also find a positive and significant impact for ULL. However, in their case, under the fixed effects model the impact of ULL is of a similar size (slightly smaller) than inter-platform competition. Given the similarity on the estimation approach and the control variables, the difference in the results is likely due to the difference in the sample, in our case including a wider set of countries and covering a more recent period. Gruber and Koutroumpis (2012) also find a positive impact on broadband adoption from ULL, which is in contrast to inter-platform competition where they find no impact. However, their measure of inter-platform competition is more a measure of technology concentration than competition, since they measure inter-platform competition as the sum of the squared technology shares of each platform.[28] This means that a reduction in the index, which is interpreted as higher inter-platform competition, does not necessarily imply a higher level of inter-platform competition (for example, if the incumbent operator offers broadband services also through other technologies, like FTTH).

4.2. Does intraplatform competition displace interplatform competition?

In this paper we deal with a number of novel questions related to whether the impact of inter- and intra-platform competition may be subject to diminishing returns, the potential existence of crowding out effects between inter- and intra-platform competition and the possibility that the impact of inter- and intra-platform competition depends on the stage of broadband diffusion.

The three questions above are highly relevant for regulators. Compared to existing papers, the answers to these questions will provide regulators with a more thorough understanding of the appropriate policy mix. To estimate whether intra- and inter-platform

[28] See Gruber and Koutroumpis (2012), page 12.

Table 2
Results of the extended specifications (diminishing returns and crowding out effects).

Variable	(1) Diminishing returns	(2) Diminishing returns + crowding out effects
Inter-platform share	0.338***	0.648***
	(0.128)	(0.150)
Inter-platform share squared	−0.281**	−0.561***
	(0.141)	(0.168)
ULL	0.737***	0.932***
	(0.238)	(0.249)
ULL squared	−1.079*	−1.398**
	(0.611)	(0.586)
Bitstream	0.085	0.648
	(0.305)	(0.477)
Bitstream squared	−2.191*	−3.516**
	(1.279)	(1.849)
Resale	−0.529**	−0.290
	(0.245)	(0.226)
Resale squared	0.305	0.408
	(0.607)	(0.454)
Inter-platform interacted with ULL		−0.927*
		(0.510)
Inter-platform interacted with Bitstream		−1.704
		(1.111)
Inter-platform interacted with Resale		−1.107***
		(0.424)
Log(GDP p.c.)	0.138***	0.150***
	(0.029)	(0.027)
Population density	0.000***	0.000***
	(0.000)	(0.000)
Education	0.003**	0.003***
	(0.001)	(0.001)
Constant	−1.405***	−1.591***
	(0.289)	(0.269)
Regional dummies	Yes	Yes
GDP p.c. instrumented	Yes	Yes
Time fixed effects	Yes	Yes
Number of observations	335	335
R2	0.899	0.905

Note: *, **,*** denote significance at 10%, 5% and 1% respectively. Robust standard errors in parentheses.

competition are subject to diminishing returns, we have added squared terms for inter-platform and the different forms of intra-platform competition. Negative coefficients on the squared terms would imply that the competition measures are subject to diminishing effects. Our estimation approach is as follows:

$$Takeup_{it}=Constant+\beta_1 ULL_{it}+\beta_2 Bitstream_{it}+\beta_3 Resale_{it}+\beta_4 Interplatform_{it}+\beta_5 Interplatform_{it}^2+\beta_6 ULL_{it}^2+\beta_7 Bitstream_{it}^2+\beta_8 Resale_{it}^2 + \beta_9 Time_t+\sum\beta_j Socioeconomic_{it}+\sum\beta_k Regional\_dummy_{it}+\sum\beta_l Time\_dummy_{it}+Error_{it}$$

The above equation has been extended to also account for a potential crowding-out effect between inter-platform competition and the different forms of intra-platform competition. Negative coefficients on the interaction terms would imply that there is a crowding out effect. In other words, the impact of the different forms of intra-platform competition is lower when inter-platform competition is already high. We have estimated the following equation:

$$\begin{aligned} Takeup_{it} &= Constant+\beta_1 ULL_{it}+\beta_2 Bitstream_{it}+\beta_3 Resale_{it}+\beta_4 Interplatform_{it}+\beta_5 Interplatform_{it}^2 \\ &+\beta_6 ULL_{it}^2+\beta_7 Bitstream_{it}^2+\beta_8 Resale_{it}^2+\beta_8 Interplatform_{it}*ULL_{it} \\ &+\beta_9 Interplatform_{it}*Bitstream_{it}+\beta_{10} Interplatform_{it}*Resale_{it}+\beta_{11} Time_t+\sum\beta_j Socioeconomic_{it}+\sum\beta_k Regional\_dummy_{it} \\ &+\sum\beta_l Time\_dummy_{it}+Error_{it} \end{aligned}$$

The results shown below include time fixed effects, regional dummies and control for the endogeneity of GDP p.c. (Table 2).

The above results have important implications for policymakers. They show that both inter-platform competition and ULL are subject to diminishing returns. Hence, while both forms of competition contribute positively to broadband take up, their impact becomes smaller as their share increases. Further, there is evidence of a crowding out effect. That is, ULL is less effective in enhancing broadband penetration for high levels of inter-platform competition. This is reflected by the negative coefficient on the interaction between ULL and inter-platform competition.

As shown by the following graph, the impact of ULL on take-up depends on both the level of ULL and inter-platform competition. If the starting share of ULL is relatively high (i.e. 20%), then we estimate that the impact of additional ULL on take-up would be

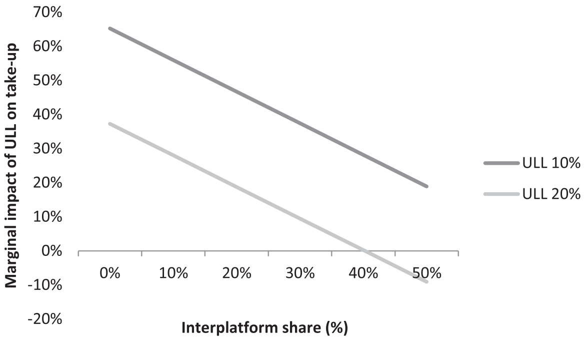

Fig. 3. Marginal impact of ULL on take-up with varying levels of inter-platform competition.

positive where inter-platform competition share is lower than 40%. If the starting share of ULL is relatively low (e.g. 10%), then the impact of additional ULL on take-up will be positive for higher levels of inter-platform competition (Fig. 3).

The share of inter-platform competition is much higher in Central and Eastern European countries (close to 50% on average). This means that there may be little benefit from significantly increasing the share of ULL in these countries. In contrast, there has been more scope for ULL to have a positive impact on take-up in Western European countries, where the share of inter-platform competition is significantly lower.

The negative quadratic term on ULL also implies that the impact of ULL will fall, as the share of ULL increases. Put another way, there is a diminishing effect to promoting ULL the higher the starting level of ULL. The following figure shows how the impact of ULL depends on the share of ULL, assuming that the share of inter-platform competition is at its 2011 average (34%). As can be seen, the impact of ULL is high at lower levels of ULL and remains positive until the share of ULL reaches 22% (Fig. 4).

One needs to be careful with the interpretation of these results when deciding on the most appropriate policy mix at a country level, as there are a number of country specific factors that would be expected to affect take-up. For example, in some countries, the level of inter-platform competition is particularly strong in urban areas, where the share of inter-platform competition can be up to 30–60%, whereas the overall national share of inter-platform competition may be lower. A policy of explicitly/pro-actively promoting ULL in such areas may not be as effective as predicted by our analysis, which is based on national shares.

The results also need to be carefully interpreted in relation to lessons for newly deployed fibre networks. If the objective is to increase super-fast broadband take-up, and the transition from (copper based) broadband to fibre broadband is 'similar' to the transition from narrowband to broadband, then the 'starting' position for countries in terms of fibre take-up may well be very different to their current position on 'standard' broadband. A few countries with high inter-platform competition and ULL may have exhausted the benefits from ULL on copper. However, this does not mean that intra-platform competition could not be a useful policy for promoting the take-up of fibre in these countries.

It is also worth noting that our results purely look at the impact of intra-platform competition on take-up. Our analysis does not look at the impact of intra-platform competition on investment incentives, which is an issue that is being discussed for fibre.

As suggested by Cincera et al. (2012) and observed by Belloc, Nicita, and Rossi (2012) when considering the impact of supply and demand broadband policies, we have checked whether the impact of inter- and intra-platform competition depends on the stage on the level of take-up. We have tackled the question through a quantile regression, estimating the impact of the different variables for different levels of broadband penetration. This is a slightly different question to the one considered above, where we looked at whether inter- and intra-platform competition had diminishing effects. The quantile regression shows whether the impact of the competition variables change as broadband take-up increases, rather than as the competition variables increase.

The results are shown in the table below for the different broadband quartiles, controlling for time fixed effects, regional

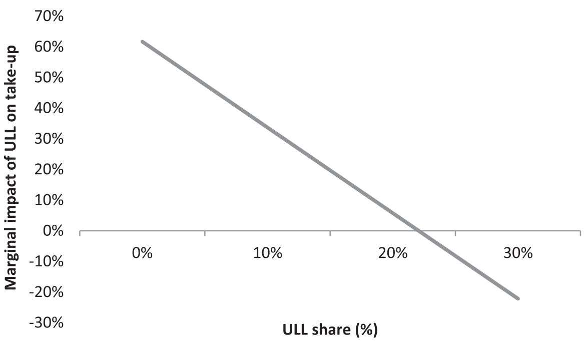

Fig. 4. Marginal impact of ULL on take-up with varying levels of ULL competition.

Table 3
Results of the quantile regression.

Variable	(1) Lower quartile broadband take-up	(2) Median broadband take-up	(3) Upper quartile broadband take-up
Inter-platform competition (%)	0.199***	0.160***	0.064
	(0.041)	(0.043)	(0.047)
ULL	0.403***	0.353***	0.227**
	(0.093)	(0.081)	(0.089)
Bitstream	−0.447***	−0.356***	−0.302**
	(0.111)	(0.135)	(0.132)
Resale	−0.337***	−0.494***	−0.571***
	(0.093)	(0.090)	(0.071)
Log(GDP p.c.)	0.163***	0.165***	0.173***
	(0.016)	(0.015)	(0.020)
Population density	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
Education	0.003***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)
Constant	−1.700***	−1.667***	−1.693***
	(0.176)	(0.164)	(0.210)
Regional dummies	Yes	Yes	Yes
GDP p.c. instrumented	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Number of observations	335	335	335
R^2	0.692	0.700	0.709

Note: *, **,*** denote significance at 10%, 5% and 1% respectively. Standard errors between parentheses.

dummies and the endogeneity of GDP p.c. (applying a control function approach) (Table 3).[29]

As expected, we observe a different impact from inter- and ULL competition at different stages of broadband penetration, observing a sort of diminishing effect with regards to broadband penetration. As such, both inter-platform and ULL are most effective for lower levels of broadband take up.

5. Conclusion and policy implications

There has been an extensive debate about the impact of broadband access regulation. This is especially relevant at the moment given the current debate about the best way of encouraging the roll-out and take-up of new fibre broadband services. This paper looks at the impact of access based entry (or intra-platform competition) on the take-up of broadband services using a data set for EU27 countries.

Our main result is that ULL had in general a positive impact on take-up - a result that is robust to a wide range of specifications. The impact of inter-platform competition is of a similar magnitude in our main specification, although its impact is more sensitive to the specification used. This may well be because the share of inter-platform competition has shown less variation over time within countries, which makes it more difficult to accurately estimate its impact.

The results for bitstream and resale are more volatile. In some specifications the results are insignificant, whereas in other specifications the results are negative. For copper networks, the European Commission has put significant emphasis on ULL. This is consistent with the results found for ULL. If these results are at least partly a reflection of the regulatory approach to ULL on copper networks, the implication would be that the regulatory approach to wholesale broadband access on copper could also impact the take-up of fibre based broadband.

Our paper considered a number of novel questions. We looked at whether ULL and inter-platform competition are subject to diminishing effects, whilst also considering whether their impacts are dependent on one another. We found that both variables exhibit diminishing effects and there is some evidence of a crowding out effect. Countries with relatively high ULL and/or inter-platform competition may therefore have exhausted the benefits from ULL on copper networks - this will need to be considered carefully at individual country level, to reflect the differences in the degree of infrastructure based competition in different parts of the same country.

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[29] See footnote 22.

Appendix A

Summary of the data

This section provides additional information on the data that we have used.
The following table shows how all of our variables have been calculated and the data sources Table A1.
The table below contains the descriptive statistics of the variables used in the analysis Table A2.
The following table shows that we do not have high correlations between our key explanatory variables Table A3.

Table A1
Variables used in the analysis.

Variable	Measurement	Source	Countries and time period
Broadband penetration	Total number of broadband lines/number of households	European Commission (EC)	EU27 Jan 04 – July–11
Inter-platform percent	New entrant non-DSL lines/ Total number of broadband lines	EC	EU27 Jan 04 – July–11
Intra-platform percent	(Full ULL lines + Shared ULL lines + Bitstream lines + Resale lines) / Total number of broadband lines	EC	EU27 Jan 04 – July–11
ULL percent including shared	(Full ULL lines + Shared ULL lines) / Total number of broadband lines	EC	EU27 Jan 04 – July–11
Bitstream percent	Bitstream lines / Total number of broadband lines	EC	EU27 Jan 04 – July–11
Resale percent	Resale lines / Total number of broadband lines	EC	EU27 Jan 04 – July–11
GDP per capita PPP	GDP per capita adjusted for PPP	Eurostat	EU27 2004–2011
Population density	Number of people per km^2	World Bank	EU27 2004–2011
Education	% of 25–34 year olds with tertiary education	Eurostat	EU27 2004–2011

Table A2
Descriptive statistics.

Variable	Obs	Mean	Overall Std. Dev.	Between CV	Within CV	Min	Max
Inter-platform share	356	0.308	0.206	67%	20%	0.000	0.982
Intra-platform share	356	0.172	0.148	81%	35%	0.000	0.526
ULL share	356	0.094	0.110	98%	67%	0.000	0.490
Bitstream share	356	0.050	0.063	106%	68%	0.000	0.347
Resale share	356	0.031	0.074	192%	141%	0.000	0.503
GDP per capita (PPP) (000 s)	356	22.876	14.920	66%	10%	4.000	82.100
Population density	356	175.030	239.550	139%	2%	17.165	1,299.984
Education	356	31.360	9.648	30%	10%	12.900	50.400
Time	356	8.500	4.615	0%	55%	1.000	16.000
Northern Europe dummy	356	0.296	0.457	158%	0%	0.000	1.000
Western Europe dummy	356	0.222	0.416	191%	0%	0.000	1.000
Eastern Europe dummy	356	0.222	0.416	191%	0%	0.000	1.000
Southern Europe dummy	356	0.222	0.416	191%	0%	0.000	1.000

Table A3
Correlation matrix.

	Inter-platform share	Intra-platform share	ULL share	Bitstream share	Resale share
Inter-platform share	1.000				
Intra-platform share	−0.596	1.000			
ULL share	−0.572	N/A	1.000		
Bitstream share	−0.320	N/A	0.148	1.000	
Resale share	−0.116	N/A	0.055	−0.124	1.000

Table A4
Results of the fixed effects and random effects tests.

Test	H_0	Statistic	P-value
Breusch-Pagan	Var(u) constant	chibar2(01) = 791.28	0.00
Hausman	difference in coefficients not systematic	chi2(8) = 44.64	0.00

Fixed vs. random effects

The Breusch-Pagan Lagrange-multiplier test for random effects rejects the null hypothesis that there are no unobserved time invariant country effects.

We have also implemented the Hausman test to compare the fixed and random effects models. As shown below, the null hypothesis that there is no significant difference between them is rejected, which suggests that counry fixed effects are important Table A4.

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