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Pau Palop García[1], Basanta Thapa[2], Prof. Dr. Dr. Björn Niehaves[2]

[1] Humboldt Universität zu Berlin, Berlin, Germany
pagarcip@hu-berlin.de
[2]Hertie School of Governance, Berlin, Germany
(thapa, niehaves)@hertie-school.org

Abstract. Reducing the digital divide is one of the main policy objectives of the "Europe 2020 Strategy" (2010) and the "Riga Declaration" (2006). To this end, the EU transfers structural funds for broadband expansion to regional governments rather than to the national level which is typically seen as the decisive actor in broadband expansion. To explore the relevance of the regions in widening broadband access, we analyze the influence of economic, demographic and institutional factors on broadband expansion at the regional and national level. In order to account for the interplay between both levels of government, we employ a multi-level regression model. We find that regional level variables are able to explain part of broadband access improvement. Significant variables are ERDF expenditure dedicated to broadband expansion, the status of regional broadband diffusion in 2008 and the national degree of inter-platform competition. The paper concludes that, although there is evidence of the role of the regions in the European policy process, the national level still performs an important gatekeeper function and that national ICT strategies are needed to successfully close the geographical digital divide in the EU.

Keywords. Broadband · Digital Divide · e-exclusion · regions · ERDF

1 Introduction

Closing the digital divide between regions is a major objective of the European Union (EU). Information and communication technology (ICT) have hugely gained in importance on the EU agenda since the Bangemann Report in the early 1990s [1], and the Riga declaration in 2006. Nowadays, ICT is seen as a key driver of economic competitiveness by the European Commission, EU member states and policy analysts alike [1], but also as a potential new source of spatial inequalities among European regions. To bridge this digital divide, the EU has introduced the Digital Agenda setting ambitious ICT goals to be accomplished by 2020, especially in the area of broadband coverage [2]. To this end, the European Commission channels financial support through the European Structural Funds to the European regions, thus effectively by-

passing the national level of the member states and empowering the regions [3]. However, it remains unclear whether regions are the appropriate level for policy measures on broadband expansion. Typically, national agencies are in charge of the design and implementation of broadband expansion strategies as well as the regulation of the broadband market [4]. Thus, the provision of EU funds for this objective to the regions may unnecessarily turn broadband expansion into a complex multi-level governance issue without improving policy impact. While the role of the regions in policy formulation and implementation has been the subject of a whole body of literature on multi-level governance [5, 6], the regions' role in broadband expansion has not been examined yet.

In order to address this research gap, the main objective of this study is to examine to what extend the European subnational level is able to explain the differences in the expansion of broadband – and therefore in closing the digital divide – in the EU. In other words, we analyze whether regional governments' policies on broadband expansion have produced observable results in bridging the digital divide in the EU. Findings in this regard are of direct relevance to the way the EU's Digital Agenda is implemented.

The remaining paper is structured as follows: First, we review related work on broadband diffusion to identify determining factors for broadband expansion on the regional as well as the national level. Then, we develop a multi-level regression model. This analysis is applied to the broadband improvement of 114 EU (2008-2012). Finally, we discuss our results and their implications for theory and policy.

2 Related Work

2.1 Broadband Diffusion

Since the mid-2000s, scholars from different disciplines (mainly economics, information systems, computer and political science) have tried to explain why some countries have expanded their broadband networks faster than others. The existing explanatory models propose a diverse set of factors: For instance, economic studies focus on market characteristics such as competition or prices [7, 8] while policy-oriented studies highlighted the impact of regulatory policy and governance structures on broadband diffusion [9]. In this section, we review the discussed drivers of broadband expansion in three categories: economic, demographic and institutional factors.

2.1.1 Economic Factors

Most of the literature on broadband expansion has been focused on economic factors. Questions such as how the level of market competition is related to the improvement of broadband access or what the effect of overall economic performance on broadband expansion is have been addressed by different scholars in the past two decades. Although efforts to find out the effect of economic variables on broadband expansion have been made before, the conclusions of these studies vary. For example, Bouckaert et al. (2010) studied broadband penetration in 20 OECD countries focusing

on competition as the main explanatory variable[1]. The authors observed a significant positive effect of inter-platform competition and a significant negative effect of service-based intra-platform competition on broadband diffusion. Additional variables, such as time trend, Gross Domestic Product (GDP), volume of personal computers, population density, and price proved significant in the model [7].

In a comparative study on fixed and mobile broadband networks, Lee et al. (2011) also distinguished between the above-mentioned three types of competition, finding that unbundled local loop (ULL), income, population density, education and price were significant factors affecting broadband diffusion [8].

Comparing broadband adoption among US states, Aron and Burstein (2003) concluded that inter-platform competition is the key variable to explain broadband diffusion [10]. Similarly, Grosso (2006) found that income, competition and unbundling were significant drivers for broadband diffusion in his study of 30 OECD countries [11].In a study of 100 countries, Garcia-Murillo (2005) focused only on the impact of unbundling on broadband deployment. She found that unbundling an incumbent's infrastructure was only significant in middle-income countries. In addition, her study showed that GDP, population and competition had a positive effect on broadband diffusion [12]. In 159 countries Lee and Brown (2008) also found that platform competition, ULL, broadband speed, ICT use[2] and content[3] contribute significantly to the adoption of broadband technologies [13].Examining broadband diffusion in five Latin American countries, Ngwenyama and Morawczynski (2009) observed a significant positive effect of GDP on broadband diffusion, as well as a negative impact of prices. In terms of education-related variables it emerged that only the number of universities in a country had a positive significant effect [14].

In one of the hitherto most holistic models of broadband diffusion, Cava-Ferreruela and Alabau-Munoz (2006) found competition, the cost of deploying, infrastructure, economic indicators and demographic indicators to be significant [15].Cadman and Dineen (2006) hypothesized that less concentrated broadband markets, led to higher broadband penetration. They found that the Herfindahl-Hirschman Index (HHI),[4] a market concentration measurement, could explain 82 percent of the variation in broadband penetration in 21 EU countries [16].In a recent study, Yates and colleagues (2013) tested if national policy initiatives, regulatory measures and governance practices have an impact on mobile broadband diffusion. Using data from 121 member countries of the OECD and regression analysis, the authors concluded that only the level of competition, the aggregate income of the country and the ICT basket prices had a significant impact on mobile broadband diffusion [9].

Based on this review, we include economic indicators in our model. First, the level of market competition, measured by the Herfindahl-Hirschman Index for inter and

[1]They distinguished between three types of competition. Inter-platform competition and intra-platform competition (divided between facility-based and service-based).

[2] Personal computer penetration per 100 inhabitants.

[3] Internet hosts per 100 inhabitants.

[4] Share of the market and the shares of other platforms used in the country for broadband.

intra-platform competition. Second, we include GDP and unemployment as indicators of economic performance.

2.1.2 Demographic Factors

Different demographic factors have also proven relevant to broadband diffusion. Tertiary education, for example, is found to be an important factor in broadband expansion [14]. On the other hand, in their comparison of 30 OECD countries, Bauer et al. (2005) found that not only economic variables were significant to explain broadband diffusion, but also the level of urbanization (operationalized as population density) [17]. Accordingly, we introduce population density and the aggregated level of education as demographic factors into our model.

2.1.3 Institutional Factors

In recent years, institutional factors have received increasing attention in studies on broadband diffusion. For example, Gulati et al. (2011) controlling for economic, political, social and educational factors, found that countries with better governance and higher investment in ICT experience faster broadband diffusion [18].

Turk et al. (2008) studied factors and strategies that foster the adoption of broadband networks in the EU, identifying e-service usage and the ICT sector environment as significant indicators. Their study also concluded that penetration and diffusion of broadband are not the outcome of a single factor, but of an 'interplay' between different factors [19] (p. 948). Thus, we incorporate institutional variables both at the regional and national level in our model.

3 Research Design

3.1 Research Question & Hypothesis

Following our research objective and the theoretical discussion above, our study challenges the established idea that the national level is the most relevant level of government in broadband expansion. Therefore, our research question reads:

RQ: Is the regional level relevant in bridging the digital divide in the EU?

ICT strategies, especially concretely broadband expansion policies, are usually implemented at the national level. Central governments are typically responsible for regulating market competition, orchestrating comprehensive infrastructure plans, or devising e-government strategies and digital inclusion policies. However, to examine the EU's policy of channeling ICT infrastructure funds to the regional level, we assume that the regions play a significant role in broadband expansion. More precisely, we argue that policies at the regional level of government impact the pace of broadband expansion in that territory. Therefore, the main hypothesis of this paper reads:

H1: Regions that actively follow a broadband expansion strategy are closing the digital divide faster than regions without a broadband expansion strategy.

When we refer to the "regional level", we mean not only the regional characteristics (economic, demographic or institutional), but especially to policies or strategies developed at the subnational level by regional institutions. In this paper, we argue that the EU regional level has two main paths to influence broadband expansion. First, by developing an ICT strategy that includes broadband expansion goals. And second, by using the ERDF to foster broadband. Based on this two influence paths, we break down the main hypothesis in two sub-hypotheses:

H1.1. Regions that developed a specific regional ICT policy that included broadband expansion are closing the digital divide faster than regions without a specific regional ICT policy.

H1.2. The more ERDF funding a region allocates to broadband expansion, the greater the improvement of broadband access.

If decisions taken by governments at a regional level – such as the amount of ERDF dedicated to broadband expansion or the development of a specific ICT strategy – are able to explain a large part of the variance of broadband expansion, this hypothesis would be confirmed. This means that the relevance of the subnational level in closing the digital divide would be proven. In contrast, if the effect of the regional level disappears when controlling for national characteristics, the hypothesis would be falsified.

3.2 Intervening Variables

3.2.1 Dependent Variable

The dependent variable, broadband expansion, is operationalized as the improvement in the percentage of households that have broadband access in a particular region between 2008 and 2012[5]. This variable is obtained by dividing the percentage of households that had broadband access in 2012 by the percentage of households that had broadband access in 2008[6]. Therefore, the notation of the dependent variable is:

$$\text{IMPROVE} = \frac{\text{Broadband Access 2012}}{\text{Broadband Access 2008}} \quad (1)$$

[5] We choose this period of time to cover the 2007-2013 European Regional Development Fund Framework. Therefore, 2008 is selected as the baseline and 2012 as the most recent available data within this ERDF framework.

[6] Broadband access is defined as the "percentage of households that are connectable to an exchange that has been converted to support xDSL-technology, to a cable network upgraded for Internet traffic, or to other broadband technologies" [20]. Raw data was obtained from the regional database provided by Eurostat.

3.2.2 Independent Variables

Regional-Level Variables.

In our model, the economic factors included at the regional level are regional Gross Domestic Product at market prices per capita and regional unemployment rate, both extensively used in previous research on broadband diffusion. As a demographic factor, population density is included as a proxy for a region's level of urbanization [13]. Regarding institutional variables, the model includes a measurement of regional authority (Regional Authority Index, RAI) proposed by Hooghe, Marks and Schakel [21, 22]. It is well established in the literature that the role of the regions depends to an important extent on the member states, in this sense, Hooghe (1996) demonstrated the "[...] considerable variation in the degrees of multi-level governance through partnership across Member States, in large part shape by the pre-existing territorial distribution of power. Thus, where a strong national government was determined to retain control over the domestic impact of structural policy, it retained considerable powers to do so" [21] (p.207).

In addition, two variables related to the ESF are included. First, ICT expenditure per capita allocated by the regions during the ESF framework 2007-2013[7] (R.EXPEN). This variable is calculated on the basis of data from the Operational Programmes (OPs) presented by the regions and approved by the European Commission for the funding period 2007-2013. In their OPs, the regions and member states had to classify the expenditure in 74 given categories proposed by the Commission. One of these categories (category 10) is related to Internet and broadband expenditure. For the regions that assign funding to category 10, the total amount of resources dedicated is registered and then divided by the total regional population.

The second variable is a binary variable that registers if a region designed a specific ICT policy during the 2007-2013 period (R.ICTPOL). The information for this variable was obtained from the Regional Innovation Monitor database of the European Commission and our own internet-based search (top 20 results of Google search for "ICT policy OR Information Communication Technology OR Innovation Policy AND *Name of the Region*" in the respective regional/national language)[8].

The Regional Broadband Access Score of 2008 (R.BROAD2008) is included as a control variable. It is assumed that the diffusion stage in which a given region is at in 2008 would determine broadband access improvement[9].

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[7] Council Regulation (EC) No. 1083/2006 of 11 July 2006 establishes that all Member States that joined the EU before 2004 had to ensure that the 60 per cent of expenditure for the Convergence objective and the 75 per cent of expenditure for the regional competitiveness and employment objective matched the Lisbon Agenda strategic priorities (Art. 9).

[8] Regions with languages that could not be covered by the author were coded "-1". The variable was developed between 20/06/2013 – 4/08/2013. The countries included in the analysis are: Austria, Germany, Denmark, Spain, Portugal, Italy, Netherlands, Belgium, Finland, Sweden, Ireland and the United Kingdom.

[9] For example, it is expected that regions with a 90 percent broadband access rate in 2008, and therefore at the last stage of the diffusion curve, would have improved less than regions at an earlier stage of diffusion (such as regions with a broadband access rate of 40 percent in 2008, for instance).

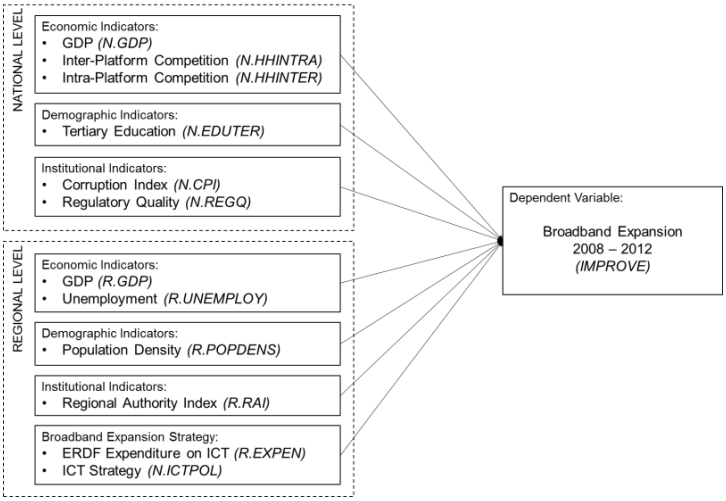

Fig. 1. Research Model (own elaboration)

National-Level Variables.

The national-level variables roughly follow the same pattern as at the regional level. Therefore, national GDP per capita (N.GDP) as well as the national unemployment rate (N.UNEMPLOY) are included in the model. The share of students in tertiary education (N.EDUTER) has also been included as a proxy to capture the level of education in a given country [8], [22]. In this paper, in accordance with Distaso et al. (2006), the standard Herfindhal Index (HHI) is used to measure intra-platform competition (N.HHINTRA). Based on the platform market shares, the Standard Herfindhal Index for inter-platform competition (N.HHINTER) is included in order to operationalize the level of competition between different technological platforms that offer broadband[10].

Finally, in line with the work of Yates et al. (2013), two institutional-related variables are included. First, the Corruption Perceptions Index 2012 (N.CORRUPTION), provided by Transparency International. Second, the Regulatory Quality Index 2012 (N.REGULATION), proposed by the Worldwide Governance Indicators, that provides information about citizens' perception of the ability of government to devise and implement regulations that permit and promote private sector development [23].

3.3 Research Model

While previous research on broadband diffusion focused on the national level, EU funding for broadband expansion is channeled to the regional level. Our model there-

[10] Data for HHI_{intra} and HHI_{inter} is provided by Distaso et al. (2006). HHI_{intra} provides a relative measure of concentration within the DSL technology, HHI_{inter} is a more general measure of the absolute concentration of the broadband market (Distaso et al., 2008, p.9)

fore explores whether broadband expansion could be determined by the regional rather than the national level (see Figure 1).

4 Methodology

4.1 Method Selection

This paper uses multi-level regression analysis to answer the research question and test the hypothesis stated in the previous chapter. This type of regression analysis allows for the estimation of the effect of variables measured at different levels (in this case, regional and national) and also makes it possible to test if the regions behave homogeneously within the national territory [24, 25, 26]. Multi-level regression assumes that the data is hierarchically organized, with a dependent variable measured at the lowest level and explanatory variables existing on all levels [27] (p.11). In our model, we assume that regions are embedded within the national level.

4.2 Dataset

The dataset used in this study is composed of 25 variables, distributed between the dependent variable (IMPROVE) and two groups of independent variables, one with the variables measured at the European regional level (as the DV) and one group measured at the national level. The dataset includes information on 114 regions (Level NUTS 2) in 12 countries of the EU 15: Austria, Germany, Denmark, Spain, Portugal, Italy, Netherlands, Belgium, Finland, Sweden, Ireland and United Kingdom. Thus, the dataset includes information about the 42.2 percent of the Level NUTS 2 regions of the European Union, 42.8 percent of the 28 European countries and 80 percent of the EU 15 countries[11].

4.3 Data Analysis

The final regression has been developed step-by-step, comparing different nested models and analyzing the effects of introducing or deleting variables, interactions or limitations. The lower level of the multi-level regression, level 1, corresponds to the European regions. The dependent variable, broadband access improvement (R.IMPROVE) and important independent variables, such as regional Gross Domestic Product (R.GDP), regional unemployment rate (R.UNEMPLOY), regional authority index (R.RAI), regional ICT Policy (R.ICTPOL) and regional ICT expenditure (R.EXPEN) are measured at this level.

[11] The regions of France and Greece have not been included due to a lack of information which is necessary to calculate the dependent variable. Luxembourg has been omitted because it only consists of one region. Data was obtained from Eurostat and, in the case of regional ICT policies, through our own research.

Level 2 corresponds to the national level. At this level, independent variables such as national Gross Domestic Product (N.GDP), national Corruption Perception Index (N.CPI), national regulatory quality (N.REGQ), national HHI intra-platform (N.HHINTRA) and national HHI inter-platform competition (N.HHINTER) are measured.

The variable R.ICTPOL is permitted to vary randomly across groups and it also introduces cross-level interactions: It is possible that some level 2 variables interfere in level 1. In the case of this paper, the interactions are introduced for the economic indicators. It is hypothesized that the slope between regional GDP and IMPROVE and between regional unemployment and IMPROVE within groups varies as a function of a level-2 variable, namely national GDP. This model tests whether average national GDP in a country is able to explain group by group variation in the relationship between, on the one hand regional GDP and IMPROVE and, on the other hand, regional unemployment (R.UNEMPLOY) and IMPROVE. The notation of this model is:

$$IMPROVE_{ij} = \beta_{0j} + \beta_1(R.UNEMPLOY) + \beta_2(R.POPDENS) + \beta_3(R.RAI) + \beta_4(R.ICTPOL) + \beta_5(R.EXPEN) + \beta_6(R.GDP) + r_{ij}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(N.GDP) + \gamma_{02}(N.REGQ) + \gamma_{03}(N.CPI) + \gamma_{04}(N.EDUTER) + \gamma_{05}(N.HHINTRA) + \gamma_{06}(N.HHINTER) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$
$$\beta_{1i} = \gamma_{40} + \gamma_{11}(N.GDP)$$

The first row of the equation indicates that regional broadband improvement is the result of the groups' intercept and a component that reflects the regional scores on the independent variables included. The second line states that each groups' intercept is a function of a common intercept (y_{00}) plus a component that reflects the linear effect of average group variables and a random between-group error. The third line indicates that the variable R.ICTPOL varies randomly between groups[12].

5 Results

The model (see Table 1) is able to account for the 90.0 percent of the total variance of IMPROVE (Adjusted R^2 Wald= 0.903). The significant variables are R.BROAD2008, with a negative relationship with IMPROVE (β= -0.022, p=0.00, Table 1, row 2), inter-platform competition (N.HHINTER), also positively related to IMPROVE (β = 0.54, p= 0.02; Table 1, row 12) and R.EXPEN (β = 0.003, p=0.09;

[12] Statistical analyses were carried out using R Studio version 0.97.551. Multi-level regressions were calculated using Linear and Nonlinear Mixed Effects Models (nlme) R package (v.3.1-108) developed by Pinheiro et al. (2013). Descriptives were calculated using the Procedures for Psychological, Psychometric, and Personality Research (pysch) R package (v.1.3.2) developed by Revelle (2013). To test the goodness-of-fit of the multi-level models, the goodness-of-fit-measures for linear mixed models with one-level-grouping (lmmfit) package developed by Maj (2011) was used (v. 1.0) [28, 29, 30].

Table 1, row 5). No cross-level interaction results are significant. Following Hox's (1994) recommendation, the R.UNEMPLOY and N.GDP are maintained in the model, although they are not significant (p. 27).

Table 1. Multi-level regression analysis final model (N=114)

	Value	Std.Error	DF	t-value	p-value
(Intercept)	1.9570	0.2831	95	6.91	0.0000
R.BROAD2008	-0.0223	0.0016	95	-14.26	0.0000
R.POPDENS	-0.0000	0.0000	95	-0.11	0.9125
R.RAI	-0.0015	0.0030	95	-0.49	0.6244
R.EXPEN	0.0030	0.0017	95	1.74	0.0854
R.ICTPOL	0.0060	0.0234	95	-0.26	0.7978
N.GDP	-0.0004	0.0019	5	-0.20	0.8465
N.CPI	0.0036	0.0049	5	0.72	0.4985
N.REGQ	0.2467	0.1730	5	1.43	0.2133
N.EDUTER	0.0000	0.0000	5	1.63	0.1630
N.HHINTRA	-0.2958	0.3810	5	-0.78	0.4726
N.HHINTER	0.5379	0.1671	5	3.22	0.0235
R.UNEMPLOY:NGDP	-0.0000	0.0000	95	-1.49	0.1407
N.GDP:R.GDP	0.0000	0.0000	95	0.82	0.4154

6 Discussion

6.1 Findings

Evidence of the regional level's relevance for the improvement of broadband access in the EU was found. The final multi-level regression model includes one significant regional variable related to the concrete regional ICT strategy: the expenditure of structural funding on broadband access. Unexpectedly, the fact that a given region developed a specific ICT policy during the period 2008-2012 is not relevant for the improvement of broadband access. Thus, the hypothesis of this paper is partially proven: the findings show that the regional broadband access scores for 2008 are significant for understanding the expansion of broadband across European regions between 2008 and 2012 (β= -0.022, p=0.00, Table 1, row 2). The higher the broadband access in a given region in 2008, the lower the expansion in the analyzed period. Also, the amount of ERDF expenditure spent on broadband expansion (R.EXPEN) is significant, i.e. more ERDF expenditure on broadband expenditure means stronger improvement of broadband access between 2008 and 2012 (β = 0.003, p=0.09; Table 1, row 5). The remaining regional variables do not prove significant. With regard to national characteristics, only inter-platform competition (N.HHINTER), is significant to explain broadband expansion (β = 0.54, p= 0.02; Table 1, row 12). This means that the higher the competition, the higher the improvement on broadband access.

6.2 Implications for Theory

During the past twenty years, the literature on broadband diffusion has found significant variables that could explain different broadband expansion patterns across countries. This paper makes three main contributions to the current state of broadband

diffusion. First, it shifts the unit of analysis to the regions. Although broadband access improvement is usually a centralized policy with national agencies in charge of implementation, this paper proves that regions, at least in the European context, are relevant actors. Second, the findings of this paper confirm that the degree of competition within the market is a key factor for explaining broadband diffusion [4], [7], [11], [13], [16]. The final model reveals that the regions in countries with higher scores on the inter-platform competition score, improved more during the period between 2008 and 2012. Third, this paper also demonstrates that the previous degree of broadband is highly significant for explaining broadband diffusion during the period 2008-2012.

6.3 Policy Implications

This paper provides evidence of the role that the regions play in the implementation of ICT policies and the potentially decisive role that they can have to bring forward the information society all over the European Union. Since regional ERDF expenditure turned out to be significant for broadband expansion, the current role of EU regions in the ERDF process should be reviewed. Regions, as the jurisdictions in charge of implementation of the ERDF, should participate more actively in the designing phase of the ERDF.

6.4 Limitations

As a pioneering effort to assess the role of regions in broadband expansion, this paper is not without limitations. First, our variable on the existence of a regional ICT strategy should be handled cautiously. As it is based on manual Internet searches, it likely to be incomplete. Second, our sample of EU regions is selective. Including Eastern countries could provide additional insights.

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