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Evidence From an EU-OECD Panel

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What explains aggregate telecom investments? Evidence from an EU-OECD Panel

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Abstract:

This paper analyzes the determinants of aggregate per capita investments into the telecom sector. We provide results of panel econometric estimates for EU and OECD countries covering the period from 2005 to 2013. The findings show a positive effect of infrastructure-based competition between xDSL broadband and cable-TV broadband subscriptions on investments. We use cross-country variance in open access regulations to examine their effect on investments and find a negative effect for bitstream regulations. The regression results are used to assess the magnitude of these factors, thereby providing valuable inputs to the policy debate on broadband promotion.

JEL classification: L38, L43, L52

Keywords: investment, competition, platform, ladder, unbundling, bitstream, regulation, broadband, telecom

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What drives aggregate telecom investments? Evidence from an EU-OECD Panel

1. Introduction

Broadband services facilitate social interaction, and are regarded as a key factor for the functioning of modern societies and economic activity. Especially its effects on economic growth, productivity and employment have attracted policy makers' attention (Clarke et al., 2015; Friesenbichler, 2018; Hardy, 1980; Khalil et al., 2009; Norton, 1992; Röller and Waverman, 2001). A precondition for using broadband based services is the availability of the data grid, the physical infrastructure. The arrival of next generation access technologies, especially fiber and coaxial transmissions, require different network architectures for which investments have not yet been sunk. The different speeds and qualities at which modern data grids are being deployed have led policy makers to ask how telecom investments can be accelerated (Cave, 2014; Friesenbichler, 2015). The debate *inter alia* comprises two aspects. First, there is a fierce discussion about the role of competition, and the level on which it occurs. While service-based competition is regarded to lower investment incentives, upstream-market competition – i.e. competition at the infrastructure level – might be conducive to overall investments. Second, the intensity of competition is affected by the sector-specific regulations.

The discussion about regulation and investment incentives takes place against the background of the liberalization of the telecommunication sector. The liberalization has had two guiding objectives: the introduction of competition was expected to lower prices, and it aimed at fostering the launch of new services. Regulatory instruments were implemented to establish service-based competition on existing infrastructures. This quickly led to a decrease in prices and the launch of new products and services in voice telephony, which is why the same regulatory framework was applied to the broadband sector as well. However, the fairly recent arrival of new transmission technologies – next generation access (NGA) – not only poses a step change in speed and quality of the service, but its deployment also requires substantial investments into the grid. This confronts the sector regulation with its inherent tradeoff between access regulation and investment incentives (Bourreau et al., 2012; Briglauer et al., 2013a, 2014; Cambini and Jiang, 2009; Grajek and Röller, 2012). This led policy makers to ask what drives investment performance over and above straightforward state interventions, and how sector-specific regulatory policies can be designed to incentivize investments.

This paper offers a bird's eye view on the telecom market. It empirically studies the determinants of investments into the telecommunications infrastructure at the country level. Investments are measured by the per capita capital expenditures of the entire telecom sector. We use a panel of EU and OECD member states, which covers the period from 2005 to 2013. The analysis is structured into two parts. First, we use cross-country differences to explore what technologies are more strongly associated with investments. We analyze both type and – to a lesser degree – intensity of competition. In particular, we examine if the effects of service-based and infrastructure-based competition on investments differs. Second, we explore the role of regulatory approaches on investments. In particular, we study how unbundling and bitstream regulations affect investments into the telecom sector.

We contribute to the literature in several ways. We show the impact of the presence of cable-TV networks on investments into the telecom sector at the aggregate, country level. We thereby add to the ongoing discussion of inter-platform competition, and the interplay of service-based and platform-based competition (for an overview see for instance Briglauer et al., 2014). Second, it offers a novel way to jointly examine the effects of bitstream and unbundling regulations on investments, and provides cross-country evidence of the heavily disputed effect of telecom regulation on investment. There is a substantial amount of literature discussing this topic, which typically focuses on how regulations affect certain types of providers (e.g., incumbent and other service operator, cable TV and xDSL). The results obtained are ambiguous, however. The aim of this paper is to present empirical results at the aggregate level and thereby provide another perspective. Finally, the findings are directly relevant to policy makers' efforts to facilitate investments into the telecom sector (e.g., Bourreau et al., 2012; Briglauer et al., 2013a; Cambini and Jiang, 2009; Guthrie, 2006).

The remainder is organized as follows: Section 2 provides a short overview of the institutional background across the countries in our sample. Section 3 briefly surveys the relevant literature about competition, regulation and investments into the telecom sector, from which the hypotheses are derived. Section 4 describes the data and the variables used to test the hypotheses. Section 5 presents the statistical analysis, Section 6 discusses the results, and Section 7 draws some conclusions for policy makers.

2. Institutional Background

The starting point of the discussion about cross-country differences in the infrastructure availability is the liberalization of the telecom sector, which introduced competition to the sector by allowing commercial enterprises to enter the market. The key objectives were to stimulate competition in order to lower consumer prices and launch more innovative products (Arrow, 1962; Schumpeter, 1976). To enable competition on existing network infrastructures which exhibit largely sunk costs, these had to be – at least partially – opened to entrants, which sector-specific regulation ensured. Almost all countries implemented a form of open-access regulation, in which alternative operators can rent existing infrastructures from incumbent operators (Hellwig, 2008). The regulatory measures differ in their extent to which open-access is provided, which affects the control over the network and investment decisions. One can generally distinguish between "unbundling" and "bitstream" regulation (Briglauer et al., 2013b; Gabelmann, 2001)[1].

The term "unbundling" (line sharing) refers to multiple services which are provided by more than one operator that share the same metallic cable. The incumbent maintains control of the infrastructure and continues to provide services, but allows alternative providers to lease part of the infrastructure, enabling them to provide services to the same subscriber and add parts of their own infrastructure. Typically unbundling refers to the last mile, which is hard to replicate due to cost efficiency or technical reasons. If there is "full unbundling", alternative providers have direct access to selected local loops, and can use the loop to deliver its service without interfering with other services provided in the same cable. This also allows alternative operators to use their own DSL equipment to provide broadband services.

In a "bitstream" access regime, the incumbent keeps full control of the entire network, and is obliged to sell access to a specified bandwidth. The incumbent offers a wholesale broadband product, also including modems, to alternative providers. In other words, the incumbent provides

[1] See also ITU Terms and Definitions at http://www.itu.int/oth/R0B0500000C/en (retrieved on 26 March 2019).

the part of an IP-based transmission where the actual audiovisual, video, or audio content is available in encoded and packetized form (ITU definition). Alternative operators have no control over the spectrum management and the infrastructure, and are not allowed to add other equipment. The choice of the implemented technology remains with fully with the incumbent.

Industrialized countries implemented these regulations to a different extent, leading to differences in the investment incentives. The main instrument to provide open-access has been unbundling, while different approaches were chosen with regard to bitstream access obligations[2]. Differences in the policy approaches can be structured into three groups (Bourreau et al., 2012; Cambini and Jiang, 2009; Huigen and Cave, 2008; Picot and Wernick, 2007): the US, the European and the East Asian approach.

In the United States, the Federal Communications Commission (FCC) implemented a local loop unbundling strategy to foster competition, especially in early stage, when entrants have not yet deployed their networks. Due to concerns about investment disincentives, the FCC revoked unbundling obligations in the broadband market in 2005. Another factor that distinguishes the US telecom market from other markets is the traditionally high share of cable TV providers, who had first been competing on the telephony, and later on the broadband market. Since cable TV companies are not regulated, lifting the unbundling obligation created a level-playing field and changed the US market.

The European Union provides a policy framework that is nationally implemented by the member states. In the second half of the 1990s, regulatory authorities required operators with "significant market power" to open their lines. This policy was expanded onto the then emerging broadband wholesale market by the "New Regulatory Framework". Differences in the deployment of NGA networks – also within the European Union - spurred a policy debate about the investment incentives. This debate has been fuelled by the European Commission that has announced politically desired market outcomes: Next Generation Networks capable of 30 Mbps or more for

[2] For instance, other than Korea, Japan and the US have never implemented a bit-stream obligation. There is great variance in the EU, where the provision of bit-stream access services is not mandated under European Union law. However, incumbents providing bitstream DSL services must also provide such forms of access under transparent and non-discriminatory terms or conditions to others (Directive 98/10/EC Article 16).

all citizens by 2020, and 50% of households having 100 Mbps subscriptions or higher. Investment estimates required to achieve these targets vary. The European Commission estimates a range of € 180 and € 270 billion Euros[3].

Especially South Korea, but also Japan, pursued a liberalization strategy that was strongly state-driven. South Korea's policy makers already discussed the significance of the internet for the country's economic development in the early 1990s, which led the government to promote the deployment of a data grid. This gained further momentum in the Asian crisis in the late 1990s, when the government continued to consistently subsidies the development of broadband networks. Three large programs have been implemented: from 1995-2005 KII (Korean Information Infrastructure), from 2004 to 2010 BcN (Broadband Convergence Network) and from 2009 onwards UBcN (Ultra Broadband Convergence Network) with a special focus on rural areas and the gigabit internet commercialization. It was not until 2002 that infrastructure-based competition became feasible in South Korean as regulators implemented local loop unbundling[4].

These regulatory approaches led to substantially different market outcomes, with regard to the deployment of conventional xDSL broadband, as well as NGN technologies, such as fiber-to-the-cabinet or fiber to the home. Figure 1 depicts the penetration ratios of fixed, mobile and cable-TV based broadband. The countries with the highest usage rates are Japan, South Korea, the United States and Switzerland. Most European countries seem to be lagging. There are minor differences across technologies, but countries that have high penetration ratios in one technology also tend to rank well in other technologies, which might indicate technological convergence.

Figure 1 here

[3] See https://ec.europa.eu/digital-agenda/en/broadband-strategy-policy (retrieved 11 December 2015).

[4] Japan opted for a similar strategy. While local loops were unbundled in 2000 to promote competition on the then hardly competitive market, the government implemented various programmes promoting the infrastructure developments - mainly to the benefit of the incumbent (e.g., "e-Japan", "U-Japan", "IT New Reform Strategy"). The instruments included subsidies, tax incentives and interest-free loans for broadband operators.

3. Literature Review and Hypotheses

What determines investments into the telecom sector? To answer this question the literature has reflected on the different market outcomes, and identified two broad fields of market and policy related explanatory factors, over and above direct state interventions. First, investments have been related to the mode of competition, i.e. if competition takes place on the same or on different platforms. Second, there is a long discussion about the interplay between competition and the regulatory approach implemented by authorities, which is expected to feed back on competitive dynamics.

Inter- and Intra-platform Competition

Studies examining the determinants of investment of next generation access assign a prominent role to the mode of competition. Waverman et al. (2007) argue that facility-based competition has a stronger effect on investments than intra-platform competition. The latter tends to reduce prices, but encourages the duplication of existing business models. In addition, different infrastructure platforms allow for a greater technological variety and therefore for more product differentiation, i.e. different types of innovation (Waverman et al., 2007). This finding has been differentiated by platform types. Infrastructure competition between xDSL providers and cable networks has been found to stimulate investments, and infrastructure-based competition from cable and mobile networks affect NGA investment non-linearly (Briglauer et al., 2014; Höffler, 2007; Yoo, 2014).

There is also evidence for different effects of service and platform competition. Evidence from the mobile phone industry points toward adverse investment incentives of service-based competition. The presence of virtual mobile network operators decreases investments by increasing competition in the end-market (Kim et al., 2011). As a result, there is a negative effect of service-based competition on the deployment of next generation access networks (Briglauer et al., 2013b). In addition, service-based competition and next generation access investment have been found to be negatively correlated (Yoo, 2014).

Such findings are mirrored by studies about penetration rates. Facility-based competition between xDSL broadband providers and cable-TV based internet providers has a positive impact on the broadband penetration (Höffler, 2007). Competition between cable-TV and xDSL broadband may also reflect demand side aspects, where product differentiation (Andersson et al., 2004) brings about more variety which eventually increases end consumer demand (Foros, 2004; Kotakorpi, 2007). Inter-platform competition has fostered the increase of broadband penetration rates in OECD countries, while service-based competition has had a considerably smaller effect (Bouckaert et al., 2010).

These considerations lead us to the first hypothesis, which we subsequently test empirically:

Hypothesis I: Infrastructure-based competition stimulates, while service-based competition impedes aggregate telecom investments.

Open-access Regulations

Investment-incentives and service-based competition can be reflected against an economic efficiency perspective. There is an economic trade-off between "static" and "dynamic" efficiency. The former refers to the optimal allocation of resources for a given technology and therefore low consumer prices in the short term. This is provided by service-based competition, which is ensured by open-access regulation (Armstrong, 2001). However, these hamper investment incentives, which are tied to the introduction of new services. Static efficiency, achieved by lower prices, therefore poses a trade-off with intertemporal, dynamic efficiency, achieved by innovation and investments. This trade-off is linked to access regulation and therefore the nature of competition. It has been shown that access regulations, such as unbundling, adversely affect incentives to upgrade, maintain and newly establish infrastructures (Friederiszick et al., 2008; Guthrie, 2006; Jorde et al., 2000; Valletti, 2003). The efficiency trade-off is being aggravated by the advent of NGA, putting the existing regulatory framework into question. The topic has therefore become a major concern for regulatory authorities (Briglauer et al., 2014).

There is a difference between bitstream and unbundling regulations. While bitstream regulation is the least burdensome for incumbents, it does not allow alternative providers to influence the technology of the infrastructure. The incumbent decides which local loops should be upgraded, and thereby shapes the consumer market, regardless of the eventual service provider (Gabelmann, 2001). However, the incumbent is likely to lose customers to competitors, which deters investments by the incumbent (Guthrie, 2006). This implies that bitstream regulations induce lower investments than unbundling regulations.

The rationale for open access regulations is to generate a competitive broadband market despite parts of the grid being natural monopolies. The design of the open-access regime is thought to have implications on investment decisions. Linking this thought with the first hypothesis, stating that investments are driven by inter-platform competition, is particularly intriguing from a regulatory perspective. There is an unregulated cable TV network that competes with an xDSL network on an infrastructure basis, which is subject to regulations aiming at providing service competition. The effects of such regulations on the investment incentives of the provider of the 'legacy' network are ambiguous (Bourreau et al., 2012).

There are many theoretical contributions discussing regulatory investment incentives (Bourreau et al., 2012; Briglauer et al., 2014), which typically differentiate the effects of regulations by the type of investor, with an incumbent on the one hand and an alternative operator, or other licensed operator on the other hand. For instance, it has been argued that open access obligations with a higher regulated access fee for the incumbent technology leads to lower investment incentives for the incumbent. The competitor has a strong incentive to invest, especially since an own access network is lacking at first (Inderst and Peitz, 2012). Recent theoretical models examine the role of different technologies, and argue that regulation of these two should not be independent (Bourreau et al., 2014). Another recent model finds that tight access regulation to both the legacy and the NGA networks harms NGA investment by incumbent telecoms operators, but does not affect cable operators (Briglauer et al., 2016). Another strand of literature argues in favor of basic investment sharing agreements, which may positively affect competition, but may also give fairly high investment incentives compared to alternatives, such as a no risk sharing scenario, or a joint-venture (Cambini and Silvestri, 2012, 2013).

Empirical results for the telephony markets for open access regulations, especially for unbundling, have been ambivalent. They have been found to discourage infrastructure investment by entrants, but not to affect incumbents' fixed-line investments. Ceteris paribus, entrants would have to significantly increase their investments into infrastructure if there were no access regulations (Friederiszick et al., 2008). These results can be qualitatively passed on to the broadband sector.

Early results for broadband unbundling regulations at the country level correspond are equally mixed. Extensive unbundling mandates potentially reduce broadband investment incentives, even though regulations ensuring easier interconnection with the incumbent can increase investment (Wallsten, 2006). It has also been argued that the effects change by the time horizon analyzed, so that unbundling does not contribute to broadband deployment in the short run, but seems to have significantly negative effects on the roll-out in the long run (Crandall et al., 2013). This is mirrored by the relatively poor performance of the bulk of EU countries. There is evidence from municipalities in Japan that shows that unbundling regulations hinder cable entrants from investing into own NGA infrastructure, while incumbents' investments are unaffected (Minamihashi, 2012).

Albeit a vast amount of theoretical mechanisms have been published and some studies have empirically assessed the effects of regulations, it is yet unknown what the effect of open access regulations are on aggregate investments. Hence, we formulate the second hypothesis tested in this study:

Hypothesis II: Open access regulations such as unbundling and bitstream obligations negatively affect aggregate telecom investments.

4. Data and Variables

To analyze the telecom sector's investment behavior, this study draws on quantitative information at the country-level obtained from the "ITU World Telecommunication ICT Indicators 2015" and the World Bank's World Development Indicators[5]. In addition, the regulatory variables used in this analysis were retrieved from the ICT Eye website, which inter alia contains regulatory and policy information collected directly from member countries' regulatory authorities. The dataset covers the period 2005 to 2013, and contains information for OECD and EU member countries. All monetary values are reported in United States Dollars, and have been deflated using 2005 as the

[5] See http://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx and http://data.worldbank.org/data-catalog/world-development-indicators (retrieved 24 February 2019).

base year (see Annex A for a variable definition and Annex B description of the computational details).

The dependent variable is per capita investment into the telecom sector at the country level. Following the ITU definition (ITU, 2010), the investments are also referred to as annual capital expenditure. This is the gross annual investment in telecom (including fixed, mobile and Internet services) for acquiring property and network. These include all operators (both network and virtual operators) offering services within the country. The term investment means the expenditure associated with acquiring the ownership of property (including intellectual and non-tangible property such as computer software) and plant by the operator. This includes expenditure on initial installations and on additions to existing installations, where the usage is expected to be over an extended period of time. Note that this applies to telecom services that are available to the public, and excludes investment in telecom software or equipment for internal use. The definition excludes expenditures on research and development and fees for operating licenses and for the use of radio spectrum.

The investments of the period analyzed predominantly went into the establishment of broadband networks and next generation access, respectively (Yoo, 2014). The focus on the entire sector instead of subsectors considers technological convergence of mobile and fixed broadband. The observed values vary strongly across countries. The highest per capita investments are found in Switzerland, Australia, Canada, the United States and Luxemburg. EU member states tend not to be in the group with the high investments. On the lower end, there are countries with catching-up economies (Figure 2). The deflated average per capita investment of the pooled sample amounts to 124 United States Dollars, with a standard deviation of 87. This picture changes if one looks at within-country differences. The mean per capita investments at the country level ranges from 25 to 396 United States Dollars. On average, the per capita investments at the country level are rather stable over time. The mean within-country variation coefficient is 24% (median 23%), ranging from 1% to 92% (5%-percentile: 7%; top 95%-percentile: 42%). Switzerland, Australia and Canada lead the ranking, followed by Denmark and the United States. The bulk of EU countries shows substantially lower investment rates, which is in line with previous findings (Yoo, 2014).

Figure 2 here

The first set of the key explanatory variables comprises the penetration ratios of cable-TV based broadband, fixed line and mobile broadband. Penetration ratios are defined as the number of subscriptions over the total population. Second, we use the ratio of cable-internet to fixed broadband (xDSL) subscriptions to measure both the presence and the intensity of infrastructure-based competition. This indicator is particularly motivated by the notion that platform-based competition mainly occurs between fixed internet service providers and cable-TV companies also providing internet services.

Next, two dummy variables are constructed to capture the regulatory approach towards open access. First, we measure the impact of an unbundling obligation on telecom investments. The variable takes on the value of one if there is a country-specific unbundling regulation with regard to raw copper, raw fiber or line-sharing, and zero otherwise. Second, we consider the presence of bitstream price regulations which imply a wholesale broadband obligation. The variable takes on the value of one if a country has a bitstream regulation, i.e. wholesale broadband access, and zero otherwise. Either indicator tends to be missing in the data for the years before 2008, i.e. the early years in the sample. Hence these missing values are imputed using the first available value. The analysis focuses on the presence of open-access obligations. We assume that these are sufficient to capture the effect of open-access on investments. It is possible that the level of access charges provides investments incentives (Hrovatin and Švigelj, 2013). Conceptually, the dummy variables, measuring open access obligations, should equate the results for open-access charges, which are set at the reservation price.

We control for contextual factors by including two country-specific macro-economic indicators - GDP per capita and the unemployment rate. We also control for country size (population and geographical area), as well as the degree of urbanization. These country level control variables capture between country differences. A dummy variable captures investment dampening effects due to the economic crisis. The variable takes on the value of one for the period after 2008, and zero otherwise (see Table 1 for descriptive statistics).

Table 1 here

5. Statistical Analysis

The dependent variable measuring investments into the telecom sector is positively and statistically significantly correlated with broadband penetration ratios. This refers to fixed broadband via xDSL (ρ: 0.52), mobile broadband (ρ: 0.34) and cable-TV based internet (ρ: 0.44; p-value: 0.000 for each coefficient).

To estimate the determinants of investments, we implement a series of panel-econometric regressions. The lagged dependent variable estimator uses specification uses the aggregate per capita investments of the telecom sector of country i and year t as the dependent variable. The key dependent variable contains penetration rates PEN, which is used as a proxy for competition between platforms. We include two dummies for open access regulations (REG). X' is a set of control variables containing country specific indicators. X'' are fixed effects at the country level, TIME denotes time effects for the entire sample. The estimated coefficients are denoted as β, and e is an error term.

$$\mathrm{INV}_{it} = a_t + \beta_0 \mathrm{INV}_{it-1} + \beta_1 \mathrm{PEN}_{it} + \beta_2 \mathrm{REG}_{it} + X'_{it}\beta_3 + X''_{it}\beta_4 + \mathrm{TIME}_t \beta_5 + e_{it}.$$

We use two types of estimators. First, we implement fixed effects regressions to control for country specific influences which have been found to affect investment and diffusion (Briglauer et al., 2013b). This estimator clusters the standard errors at the country level. Second, we use a dynamic lagged dependent variable estimator to address concerns of possible endogeneity (Grajek and Röller, 2012). Table 2 shows the regression results.

The regressions (1) and (2) examine the role of different technologies on telecom investments. We use broadband penetration ratios of (i) cable TV lines, (ii) fixed (xDSL) lines and (iii) mobile networks.

The number of observations drops compared to the other specifications, because data on mobile broadband are often only available in later years of the sample. The next specifications draw on the idea of inter-platform competition, and estimate the ratio of cable to fixed subscribers. They therefore capture inter-platform competition, and do not consider mobile broadband to increase the number of observations.

Estimation (3) does not, and estimation (4) does include the effect of two specific open access policies on per capita investments. These are dichotomous variables, measuring the presence of (i) unbundling and (ii) bitstream regulation. These have changed over time in some countries. The bitstream policy changed in 47.5% of the countries in the sample, while the unbundling policy changed in 12.5% of the countries.

Table 2 here

Results

The regression results for per capita investments into the telecom sector using a panel of EU-OECD countries for the period 2005-2013 show a positive effect of infrastructure-based competition.

In the first two specifications, we estimate the effect of the penetration ratios separately. The results show that most penetration rates are not significantly associated with aggregate investments. Only a higher cable TV based broadband penetration seems to exert a positive influence on investments. This effect is weakly significant in the first specification. Mobile broadband has been considered separately, because data are not available for the full sample, and including this indicator therefore reduces the degrees of freedom.

The third specifications capture Infrastructure-based competition by the ratio of cable broadband to xDSL broadband penetration rates. Mobile broadband is not considered due to its negligible coefficient in the previous estimation. The results show a robust and statistically significant effect of inter-platform competition on per capita telecom investments.

The fourth regression includes the variables capturing open access regulations. The coefficients show different results. Bitstream access regulations were found to have a negative impact on overall telecom investments. The coefficient for unbundling is statistically insignificant. The changes of the within R-squared indicate that regulatory policies explain a relatively small fraction of the variance. The R-squared increases from 23% in specification (3) to 27% in specification (4) which includes two dummy variables measuring open access regulations.

The fifth column reports the coefficients for an Arellano-Bond lagged dependent variable estimator, which controls for fixed effects by first-differencing the dependent variable. The coefficient for unbundling remains positive, but turns statistically insignificant.

By and large, the control variables perform as expected. In particular, we find a negative effect of the unemployment rate as well as the economic crisis period after 2008 on telecom investments. GDP per capita is positively associated with investments, which however turns insignificant in some of the fixed effects estimations, where the time invariant fixed effect seems to capture the effect of GDP per capita. The coefficients for total population are positive, and perhaps surprisingly – the share of the population living in urban areas are largely insignificant.

Endogeneity

It is not unlikely that regulatory authorities react to telecom providers' investment decisions. Low investments may trigger regulatory decisions aiming at stimulating investments. Hence, there might be reverse causality between regulation and investment if regulators react to the market's investment performance. This would generate a regulatory commitment problem (Grajek and Röller, 2012). We cannot perform Granger causality tests due to the short time series. However, we address possible endogeneity by implementing an Arellano-Bond lagged dependent variable estimator. This estimator has been designed for panels like the present one, with rather short periods and a larger number of groups. A GMM type instrument is used in a two step estimator to control for endogeneity due to the first differences the investment indicator; all possible lags are used. All other control variables are used as additional standard instruments for the difference equation. The post-estimation tests cannot reject this specification, and thereby control for possible endogeneity issues with internally constructed instruments (for similar applications of such an estimator, see Briglauer et al., 2013b; Cambini and Rondi, 2010). The results suggest that endogeneity issues do not seem to induce a bias that qualitatively changes the results. This is plausible, given the aggregate level of analysis. Possible reverse causality between the access regulation variables and per capita investments only affects the regulated section of the broadband market.

Robustness checks

We estimate several extensions of the econometric model to ensure the robustness of the results. These refer to both the chosen estimation method and the explanatory variables used (see online appendix). The results remained qualitatively the same.

First, we altered the estimation method. We estimated the core specification as OLS with standard errors clustered at the country level. Next, instead of using fixed effects at the country level we used random effects; a Hausman test only weakly rejects random effects (p-value: 0.027). Third, we explore serially correlated standard errors. Implementing the Wooldridge test for autocorrelation indicated serial correlation of the residuals at the 95% significance level. Hence, we estimated both a random and fixed effects linear models with a correction for AR(1) disturbances.

We then adjusted the set of explanatory variables. For instance, we included time effects measured by three year period dummies instead of a single crisis dummy. We also included the squared cable share to test for a possible inverted-U relationship between investment and infrastructure-based competition (Briglauer et al., 2013b; Friesenbichler, 2007; Höffler, 2007). The results obtained for the latter specification were statistically insignificant; we could not find a non-linear relationship.

Eventually, we consider qualitative information about the degree of competition in the broadband consumer market, be it in the fixed or the mobile segment. The data contain the respective regulatory authority's assessment of the degree of market competition, i.e. if markets were fully, partly or not competitive. We defined a dummy variable, which takes on the value of one if markets are fully competitive, and zero otherwise. Twenty percent of the observed markets were deemed to be non-competitive. Cognizant of possible measurement bias due to self reporting, we included this measure in the regressions. The estimated coefficient was negative and statistically insignificant, which is in line with previous findings of a negative relationship between service competition and investment (Yoo, 2014).

6. Discussion and Limitations

The empirical analysis explored, if telecom investments can be explained by the type of competition in the telecom sector and regulations promoting competition on established grids. These are not only interlinked, but are also central to the conceptual underpinning of the European regulatory approach. Europe's policies have followed the investment ladder theory: In a sequential process, telecom providers were encouraged to enter the market as retail service providers. They were then encouraged to upgrade their market participation by making investments into network assets, thereby climbing up the ladder of investment. Hence, providers in initial stages were encouraged to enter the market as service providers. Service provision is enabled by open access regulation. In later stages, they are expected to invest into their own network assets and are subject to infrastructure competition (Cave, 2006, 2014).

The first question which arises is whether infrastructure based competition, which is required in the latter stages of the investment ladder, promotes investments. The regression results show that a key determinant of per capita investments is platform-based competition between cable and xDSL networks, which is measured by the simultaneous presence of either technology. Mobile broadband, which indicates a more service based type of competition, is hardly associated with investment. This panel econometric result supports case study evidence from eight EU Member states which find that facilities-based competition has served as the primary driver of investments in upgrading broadband networks (Yoo, 2014).

To further explore the investment ladder theory, one can ask if competition between xDSL and cable TV based broadband has co-evolved over time, or emerged in a pattern that the investment ladder would suggest. We find that entrants have not "jumped off" the investment ladder, i.e. they have not invested into own networks on a large scale, which would have entered competition with incumbent's networks (Cave, 2014). The subscription data show that networks of cable operators were – by and large - not newly established. In countries where they have either been in place prior to the liberalization, both cable based broadband and xDSL broadband penetration rates have increased over time. Elsewhere the number of cable subscriptions expanded only at a very moderate rate, and achieved very small penetration rates in the last year of the sample. In other words, there was no sudden emergence of cable based broadband subscriptions, i.e. cable penetration ratios were either statistically significantly greater than nil in the first year of the sample, or cable providers were not present over the entire period. This implies that they were not erected by investment ladder type incentives.

In addition, service-based competition – the preceding regulation of investment races in the investment ladder approach – tends to play a minor role explaining investments. This reflects difficulties to switch from early phases of the investment ladder, in which consumer market competition is stimulated by regulatory policies, to later phases where investments are supposed to increase (Bourreau et al., 2010). In other words, there seems not to be a ladder of investment, but rather a natural co-evolution of networks, with the prerequisite of the ex ante presence of cable TV providers. This is in line with previous empirical findings for EU Member States that could not support the ladder-of-investment hypothesis that predicts a transition from local loop unbundling to new access infrastructures (Bacache et al., 2014).

The investment ladder theory rests on assumptions with regard to a replacement effect. This is, entrants benefit from profits from service-based competition, which are an opportunity cost to investment. The key assumption of the approach is that the replacement effect can be neutralized by investments into own infrastructure so that service-based competition becomes a stepping-stone to infrastructure-based competition (Bourreau et al., 2010). Did regulations provide such an incentive? If open access regulations are likely to hamper infrastructure based competition and therefore investments, switching the regulatory regime may positively affect investments. We explored the effects of the main policy instruments of the investment ladder approach in a second step. These are bitstream and unbundling regulations, which have been applied at varying degrees across countries.

The results of the dynamic panel estimation indicate that especially bitstream regulations negatively affect investments into the telecom sector. This is plausible due to the investment hampering effect of regulations that promote intra-network competition (Briglauer et al., 2014;

Cave, 2014). A shift in the regulatory strategy away from bitsream regulations mirrors a shift away from service-based competition. This is likely to increase investments, because it undermines the relative competitiveness of service providers.

The sign of the coefficients for unbundling is positive, yet weakly significant. This may indicate a fundamental difference between unbundling and bitstream regulations. Local loop unbundling seems to play a critical role in the establishment of infrastructure-based competition. Local loops are regarded as the most investment intensive section of the telecom network, and the unbundling of the last mile might be a prerequisite for platform-based competition on other layers of the grid. Hence, bitstream regulations generate service-based competition which is negatively associated with investments. Unbundling obligations not only increase the intensity of service-based competition, but also enable alternative providers to access the final consumer and therefore effectively compete with incumbents. Unbundling allows alternative providers to operate own infrastructures without owning all layers of the grid, which is positively related to investment. A regulatory regime that implements unbundling and does not use bitstream regulation may therefore accelerate investments.

The results from the dynamic lagged dependent variable model can be used for an assessment of the magnitude of the effects. In a post crisis and ceteris paribus scenario where all other variables are held at their mean, an increase in the measure of platform competition in the fixed line segment (i.e. the ratio of cable to xDSL subscribers) by one standard deviation would increase investments by approximately four percent. A stronger macro-economic environment with a 10ten percent higher GDP p.c. and a two percentage-points lower unemployment rate would lead to eight percent increase in per capita telecom investments.

Lifting existing bitstream obligations might lead to an increase in per capita investments by approximately 16%. This estimate contradicts previous results from Japan which find that forced unbundling regulation leads to a 24% decrease in the incidence of new infrastructure builders (Minamihashi, 2012). Either way, the magnitude of these effects suggests that adjustments in the sector specific regulation alone are able to promote investments, but – as stand-alone instruments – are insufficient to substantially accelerate investments in a way that the usage goals proclaimed by policy makers would require.

Limitations

Certainly, there are limitations to this study. For instance, investments were measured at the country level, amalgamating investments into fixed and mobile technologies. While providing a bird's eye view was the purpose of this paper, it cannot replace additional research about the micro-dynamics of the interplay of different technologies. The aggregate perspective accounts for technological convergence that has been observable in the period analyzed. Also, there are other factors that may matter for the investment performance of the telecom sector, which the present dataset does not contain, even though these are – at least to a certain degree – captured by the fixed effects measuring unobservable influences at the country level. These may include state aid or state ownership, the price of telecom services or the transmission speed as an indicator for the grid quality. Eventually, the investment indicator does not provide information about the digital divide, which serves as the policy rationale for the debate about broadband deployment. However, many of these indicators only change slowly, and are therefore absorbed by the fixed effects and the country-specific control variables.

7. Conclusions

In this study we empirically analyze the factors shaping aggregate per capita investments into the telecommunications sector. The indicator for investment measures the annual capital expenditure, defined as the gross annual investment into the telecom sector (including fixed, mobile and Internet services available to the public) for acquiring property and network. Hence, we offer a bird's view on the outcomes of the telecom sector. We are able to address the question about determinants of investment at an aggregate level, for which findings at the micro level have been ambiguous.

We test two hypotheses in panel of EU and OECD countries for the period between 2005 and 2013. The regression results support the first hypothesis, stating that aggregate investments are driven by platform competition between broadband via xDSL and cable TV lines. This type of competition was not policy induced *per se*, but rather a result of the co-evolution of broadband networks. We partly support the second hypothesis, and find that bitstream stifles per capita investments, which is in line with theory. We could not find strong statistically significant effects for unbundling regulations. The magnitudes of the coefficients suggest that, ceteris paribus, regulatory instruments alone are insufficient to stimulate aggregate investments.

The descriptive statistics show that telecom providers in most European invest less than their counterparts, which is consistent with previous findings (Briglauer et al., 2013b; Yoo, 2014). An implication of such a global comparison is that the investment ladder approach, the EU's regulation model, is the least conducive to aggregate investments. The results of the regression analysis suggest that the investment ladder approach is unlikely to be able to elicit the investments required for achieving the deployment targets laid out by policy documents, such as the Europe 2020 agenda (Bourreau et al., 2012; Briglauer et al., 2013b; Nitsche and Wiethaus, 2011). This affects both the upgrading of networks and the deployment of NGA-access to hitherto not served geographies (Cave, 2014). Higher investment rates, which are induced by inter-platform competition, may not be an effective means to increase overall coverage. However, they are render already covered areas more competitive (Bourreau et al., 2012). Similarly, platform based competition, which is more strongly associated with investment, seems to be the result of a co-evolution of networks rather than the outcome of investment-ladder policies.

Recent literature increasingly suggests two stylized approaches to the design of the telecom sector. Both have been argued to stimulate investments, and can be interpreted as antitheses to the investment ladder approach. Both have different implications for policy makers and social welfare (Bouckaert et al., 2010; Bourreau et al., 2010, 2012; Briglauer et al., 2013b; Höffler, 2007; Nitsche and Wiethaus, 2011). First, policy makers may leave the market largely unregulated in a market based model such as the United States. This is – as also suggested by this study – only conducive to investments, where pre-existing cable TV infrastructures compete against telecom providers. Also, this model tends to generate a substantial rural-urban divide. Alternatively, policy makers may opt for a substantially different approach, and rely on strong state interventions that directly address the general trade-off between price efficiency and investment incentives. State interventions pose a leverage to promote infrastructure investments. Yet, there are practical constraints in its implementation. These include capital obsolescence if alternative investments have already been made, possibly sacrificing some of the positive effects of the sector's liberalization. In addition, state interventions require public funding in times of budget constraints.

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Tables and Figures

Table 1 – Descriptive Statistics

	Obs.	Mean	Median	Std. Dev.	Min.	Max.
Investment p.c.	320	123.87	103.64	87.47	14.26	673.39
GDP p.c.	320	28535.84	26150.97	18236.34	3852.98	87772.69
Unemployment rate	320	8.05	7.35	4.05	2.30	27.20
Area (sq. km.)	320	824.65	100.25	2200.25	0.32	9161.92
Population, in mn.	320	31.67	10.23	53.96	0.30	314.11
Urban population (share)	320	19.33	17.88	17.01	0.00	64.12
Crisis (dummy)	320	0.58	1.00	0.50	0.00	1.00
Cable b.b., pen.	307	5.22	4.18	4.56	0.00	18.70
Fixed b.b., pen.	319	22.17	22.85	9.45	1.44	42.50
Mobile b.b., pen.	199	1.58	1.48	0.93	0.01	3.96
Cabe b.b. to fixed b.b., ratio	310	0.22	0.20	0.16	0.00	0.66
Full competition in broadband	320	0.79	1.00	0.41	0.00	1.00
Unbundling (dummy)	320	0.97	1.00	0.17	0.00	1.00
Bitstream regulation (dummy)	320	0.78	1.00	0.41	0.00	1.00

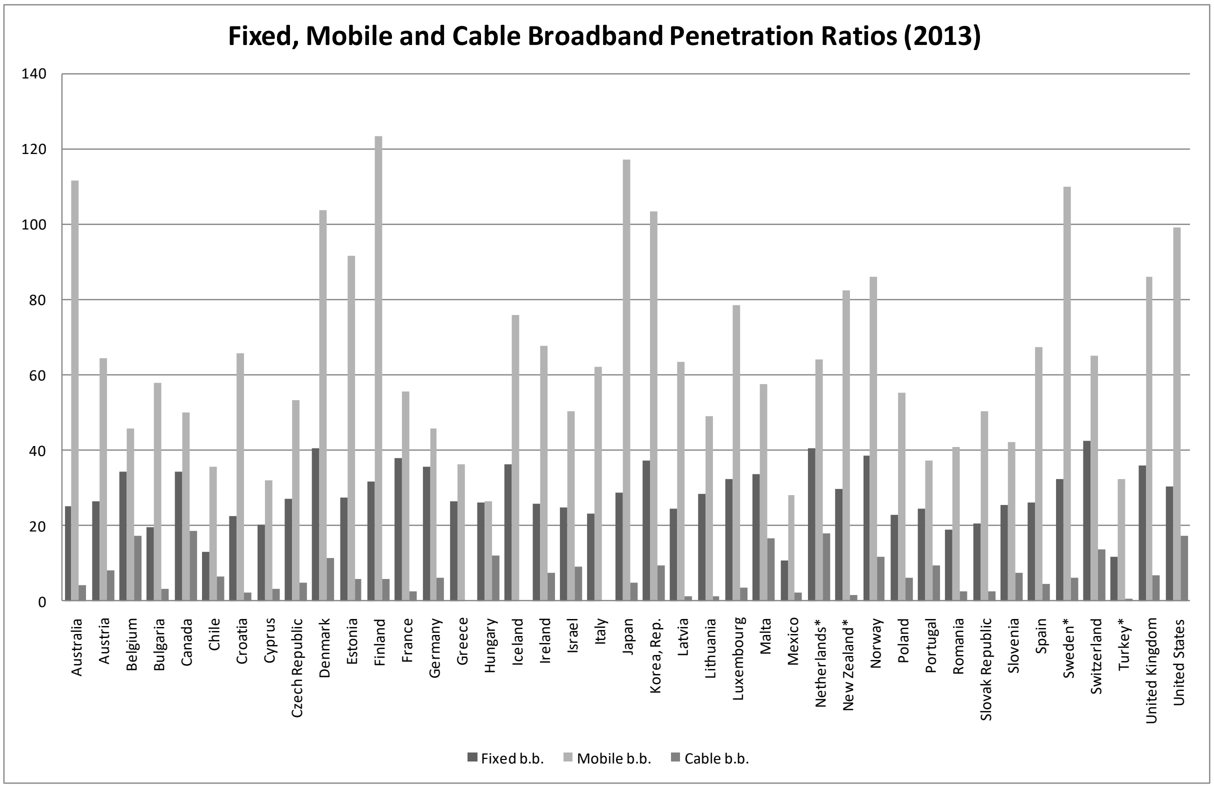
Note: This table provides descriptive statistics used in the regression analysis. Monetary values are in USD, real (base year 2005). The table only contains observations for which corresponding investment value is available. The period covers the years 2005 to 2013.

Table 2 - Regressions results for the determinants of per capita telecom investments

	(1)	(2)	(3)	(4)	(5)
Estimator	FE	FE	FE	FE	A-B
Lag Dep. Var.					0.0978***
					(0.034)
Cable b.b. (pen.)	0.0537*	0.0449			
	(0.029)	(0.032)			
Fixed b.b. (pen.)	0.0084	-0.0221			
	(0.008)	(0.019)			
Mobile b.b. (pen.)		0.0011			
		(0.002)			
Cable to fixed b.b. (ratio)			1.0329**	0.9375***	0.9516***
			(0.390)	(0.332)	(0.125)
Unbundling				0.3127*	0.0848
				(0.180)	(0.130)
Bitstream regulation				-0.2443	-0.1429***
				(0.217)	(0.049)
GDP p.c. (ln)	-0.7199	0.2325	0.2121	0.5692	0.1443
	(0.520)	(0.653)	(0.440)	(0.532)	(0.169)
Unemployment rate	-0.0357***	-0.0152	-0.0266***	-0.0186*	-0.0295***
	(0.011)	(0.015)	(0.009)	(0.009)	(0.004)
Population (ln)	1.4593	4.4449**	1.9014	2.2950*	1.3900***
	(1.555)	(1.684)	(1.417)	(1.183)	(0.301)
Urban pop. (share)	0.0285	-0.2156**	0.0337	0.0282	0.0733**
	(0.046)	(0.095)	(0.053)	(0.053)	(0.033)
Crisis (0/1)	-0.2963***	-0.3056***	-0.1703***	-0.1653***	-0.1657***
	(0.088)	(0.081)	(0.053)	(0.051)	(0.013)
Constant	-12.3919	-65.2867***	-28.9096**	-38.9239***	-21.1339***
	(14.760)	(22.878)	(14.403)	(14.447)	(4.632)
Observations	310	196	310	310	269
R-squared	0.27	0.42	0.23	0.27	
Sargan test (p-value)					0.401
A-B AR(1) test (p-value)					0.008
A-B AR(2) test (p-value)					0.449

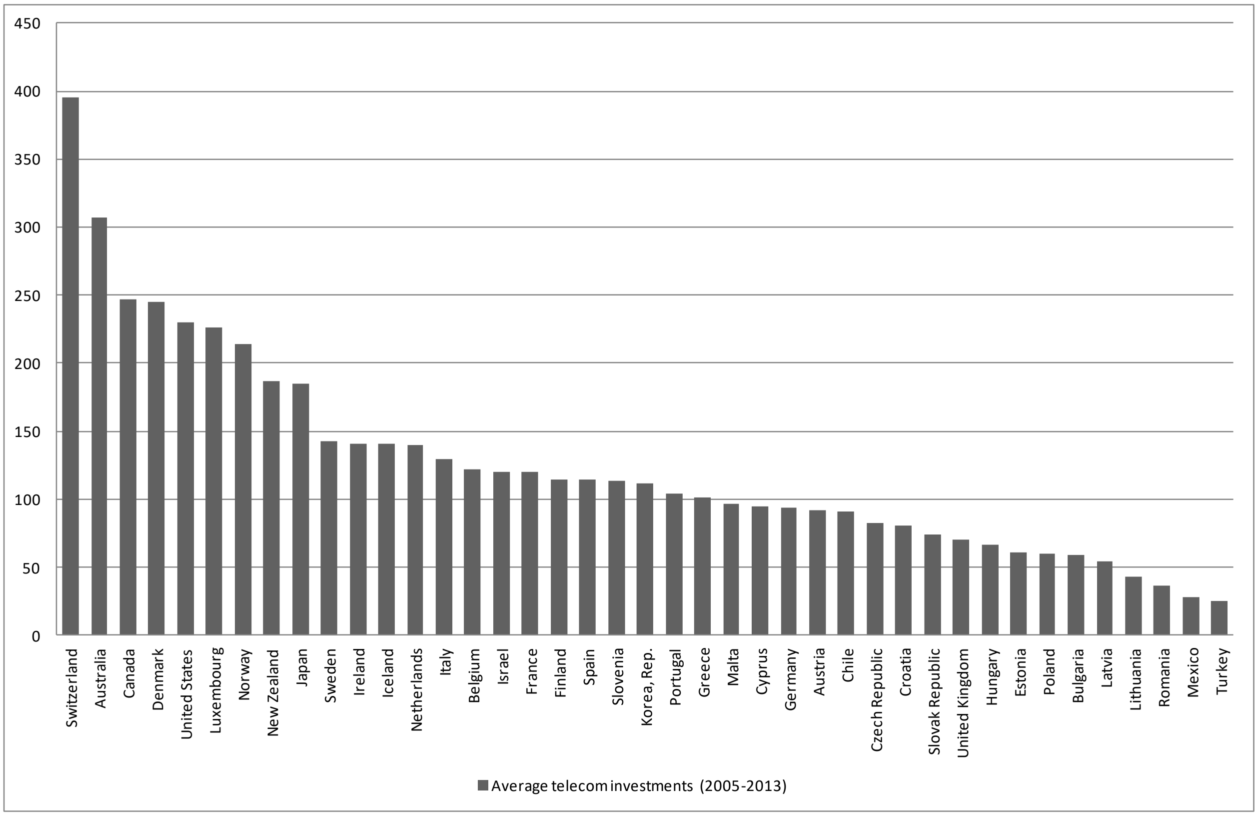
Note: This table presents the results for the fixed effects (FE) regression analysis explaining overall telecom investments per capita in natural logs. The results indicate that the driver is infrastructure competition between fixed and cable broadband. Results for unbundling are not robust, and bitstream regulations are round to be investment deterring. Standard errors clustered at the country level are reported in parentheses (except A-B). Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Figure 1 – Broadband penetration rates for fixed, mobile and cable technologies (2013)



Source: World Telecommunications / ICT Indicators Database, ITU 2015, Number of subscribers over total population. Note: This graph shows the penetration rates for fixed (xDSL), mobile and cable TV based broadband technologies. The penetration rate is defined as subscriptions per 100 inhabitants. * denotes countries for which the last available values are from 2012 (Sweden, Turkey and the Netherlands) and 2011 (New Zealand).

Figure 2 - Telecom Investments per Capita, 2005-2013



Note: This table shows the average per capita investments into the telecom sector for the period 2005-2013. All values are in USD, real (base year 2005).

Source: World Telecommunications / ICT Indicators Database, ITU 2015, own calculations.

Annexes

Annex A

	Fixed broadband penetration			Cable TV broadband penetration		
	2005	2013	Growth in %	2005	2013	Growth in %
Australia	9.9	25.2	12.4	2.3	4.0	7.2
Austria	14.3	26.3	7.9	5.8	8.2	4.4
Belgium	19.2	34.2	7.5	7.2	17.4	11.6
Bulgaria	2.1	19.6	31.9	0.7	3.1	21.1
Canada	21.7	34.4	5.9	11.2	18.7	6.6
Chile	4.4	13.1	14.7	1.9	6.6	17.0
Croatia	2.6	22.4	30.8	0.1	2.3	47.8
Cyprus	3.1	20.1	26.4	0.0	3.3	n.a.
Czech Republic	6.9	27.2	18.6	1.3	4.9	18.1
Denmark	24.8	40.4	6.3	7.2	11.5	6.0
Estonia	13.2	27.4	9.5	3.7	5.9	6.1
Finland	22.4	31.6	4.4	2.8	5.8	9.4
France	15.0	37.8	12.3	0.9	2.6	14.2
Germany	13.1	35.5	13.3	0.3	6.3	46.8
Greece	1.4	26.4	43.8	0.0	0.0	0.0
Hungary	6.5	26.3	19.2	2.1	12.1	24.4
Iceland	26.3	36.3	4.1	0.1	0.0	0*
Ireland	7.8	25.9	16.3	0.8	7.4	32.5
Israel	17.7	24.9	4.3	6.1	9.2	5.3
Italy	11.8	23.3	8.9	0.0	0.0	0.0
Japan	18.2	28.8	5.9	2.6	4.7	7.8
Korea, Rep.	25.3	37.3	5.0	8.3	9.5	1.7
Latvia	2.7	24.6	31.8	0.0	1.3	n.a.
Lithuania	7.0	28.3	19.0	1.5	1.2	-2.5
Luxembourg	15.1	32.5	10.1	1.3	3.4	12.4
Malta	12.7	33.8	13.0	5.2	16.7	15.6
Mexico	1.8	10.8	25.5	0.6	2.4	18.6
Netherlands	25.1	40.4	6.1	9.6	n.a.	n.a.
New Zealand	7.8	29.6	18.2	n.a.	n.a.	n.a.
Norway	21.4	38.6	7.6	3.0	11.6	18.6
Poland	2.5	22.8	32.0	0.6	6.1	33.2
Portugal	11.1	24.5	10.4	4.7	9.3	9.0
Romania	1.8	19.0	34.5	1.2	2.7	10.9
Slovak Republic	3.4	20.5	25.3	0.4	2.6	26.5
Slovenia	9.8	25.5	12.6	3.3	7.5	11.0
Spain	11.5	26.3	10.8	2.7	4.6	7.0
Sweden	27.9	32.5	1.9	3.9	n.a.	n.a.
Switzerland	22.4	42.5	8.3	6.6	13.6	9.3
Turkey	2.3	11.9	22.5	0.0	n.a.	n.a.
United Kingdom	16.4	35.9	10.3	4.4	6.9	5.7
United States	17.3	30.3	7.3	9.0	17.2	8.5

Note: * growth rate of cable TV based broadband in Iceland was put on zero due to the negligible share in the base year.

Annex B

Variable	Definition	Source
Investment p.c. (ln)	Annual investment in telecommunication services, in USD; deflated, base year 2005	ITU ICT Indicators 2015
GDP p.c. (ln)	GDP per capita in USD; deflated, base year 2005	WDI
Unemployment rate	Unemployment rate; total unemployment as a share of total labor force	WDI
Population (ln)	Total population	WDI
Area (ln)	Land area in square kilometers	WDI
Urban pop. (share)	Population in urban agglomerations of more than 1 million as a share of of total population	WDI
Crisis (0/1)	Dummy variable takin gon the value of 1 for the period after 2008, and 0 otherwise	ITU ICT Indicators 2015
Cable / Fixed b.b.	Ratio of cable modem internet subscriptions to fixed-broadband subscriptions	ITU ICT Eye
Mobile / fixed b.b.	Ratio of Active mobile-broadband subscriptions to fixed-broadband subscriptions	ITU ICT Eye
Unbundling	Dummy variable taking on the value of 1 if any type of local loop unbundling is required, and 0 otherwise. Unbundling types considered are raw copper, line sharing, bitstream / wholesale access, raw fibre, High frequency spectrum (or line sharing) of the local loop for the provision of ADSL systems and services	ITU ICT Eye
Bitstream price control	Dummy variable taking on the value of 1 if there is a price control for wholesale telecommunication services of the broadband access/bistream market, and 0 otherwise	ITU ICT Eye
Full competition	Dummy variable taking on the value of 1 if there is full competition in the broadband market (fixed or wireless), and 0 otherwise (i.e. if there is partial competition or a monopoly)	ITU ICT Eye

Annex C

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Estimator	OLS	RE	RE(AR)	FE(AR)	FE	FE	FE
GDP p.c. (ln)	0.6392***	0.5961***	0.6281***	0.3426	0.8033*	0.2627	0.5732
	(0.088)	(0.081)	(0.071)	(0.330)	(0.473)	(0.378)	(0.409)
Unemployment rate	0.0011	-0.0168***	-0.0148*	-0.0271***	-0.0200**	-0.0225***	-0.0186**
	(0.011)	(0.006)	(0.008)	(0.010)	(0.009)	(0.008)	(0.009)
Population (ln)	-0.0511	-0.0672	-0.0589	0.1816	2.0305**	2.6637***	2.3032***
	(0.040)	(0.048)	(0.041)	(0.211)	(0.860)	(0.754)	(0.823)
Urban pop. (share)	0.0069**	0.0076*	0.0069*	-0.0274	0.0192	0.0249	0.0283
	(0.003)	(0.004)	(0.004)	(0.023)	(0.040)	(0.036)	(0.039)
Cable to fixed b.b. (ratio)	0.7503**	0.8930***	0.6527**	0.6722	1.1183***	0.3747	0.9354**
	(0.328)	(0.271)	(0.271)	(0.841)	(0.409)	(0.878)	(0.396)
Cable - Fixed (ratio), squ.						0.8135	
						(1.281)	
Unbundling	-0.2801**	0.2494**	0.0470	-0.2378	0.2818**	0.2085*	0.3099**
	(0.133)	(0.127)	(0.132)	(0.184)	(0.136)	(0.124)	(0.135)
Bitstream regulation	-0.1331	-0.2101***	-0.1515**	-0.2373***	-0.2833***	-0.1027	-0.2431***
	(0.089)	(0.066)	(0.065)	(0.087)	(0.076)	(0.071)	(0.074)
Crisis (0/1)	-0.1613**	-0.1265***	-0.1398***	-0.1812***		-0.1502***	-0.1652***
	(0.070)	(0.036)	(0.042)	(0.048)		(0.039)	(0.043)
Fully competitive market							-0.0185
							(0.075)
Constant	-0.8067	-0.4890	-0.7476	-0.6036*	-36.9589**	-41.8049***	-39.0796***
	(0.997)	(1.168)	(1.019)	(0.313)	(15.861)	(13.273)	(14.487)
Period dummies	No	No	No	No	Yes	No	No
Observations	310	310	310	310	310	306	310
R-squared	0.638	0.237	0.218	0.434	0.248	0.254	0.266

Note: This table presents the results for the robustness checks. Clustered s.e. at the country level (1), serially correlated s.e. (3); conventional s.e. otherwise; Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The within R^2 is reported.

Annex D

The data used in this study was obtained from the World Telecommunication/ICT Indicators Database 2015 (see http://www.itu.int/pub/D-IND-WTID.OL-2015), the ITU ICT-Eye website (see http://www.itu.int/net4/itu-d/icteye/) and the World Bank (see http://data.worldbank.org/data-catalog/world-development-indicators). These websites were accessed on 30 October 2015. The constructed dataset required variable modifications and data cleaning to make an empirical analysis feasible.

All monetary values were deflated with 2005 as the reference year to make them comparable over time. The deflator was obtained from the World Bank Indicators (GDP deflator; base year varies by country), which was re-scaled to the common base year 2005. In this process, the values in the original dataset that were provided in U.S. dollars were first converted into the local currency, deflated, and then converted back into US dollars with the exchange rate for 2005. The exchange rates used were also obtained from the Word Bank Indicators (official exchange rate; local currency unit per U.S. dollars, period average). However, these time series do not include EURO countries. Eurostat data were used for the official exchange rate from EURO to U.S. dollars. For countries with missing currency information, the values of the currency effectively used were taken (e.g., Swiss Francs were used for Liechtenstein, the EURO was used for San Marino and British Pounds were used for Guernsey).

The regulatory information provided by the ITU ICT-Eye website was available for 2005 onwards. However, the variables relevant to this research are for some countries not available for the first years covered. To be able to use more observations in the statistical analysis, the first available value was imputed for the missing year(s), thereby constructing a sample which begins in 2005.