Regulation and Investment in Network Industries: Evidence from European Telecoms

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Abstract

We provide evidence of an inherent trade-off between access regulation and investment incentives in telecommunications by using a comprehensive data set covering more than 70 fixed-line operators in 20 countries over 10 years. Our econometric model accommodates different investment incentives for incumbents and entrants, a strategic interaction of entrants' and incumbents' investments, and endogenous regulation. We find access regulation to have a negative effect on both total industry and individual carrier investment. Thus, promoting market entry by means of regulated access undermines incentives to invest in facilities-based competition. Moreover, we find evidence of a regulatory commitment problem: higher investments by incumbents encourage regulated access provision.

1. Introduction

The rationale for access regulation in network industries is to intensify competition in order to promote efficiency and thereby enhance social welfare. One example of access regulation that is particularly relevant to this study is the European Union (EU) mandate that opened telecommunications markets to competition by requiring incumbent suppliers to unbundle their networks and make the network elements available to retail competitors at regulated prices

We thank Martin Cave, Martin Peitz, David Salant, Ingo Vogelsang, the editor, and the anonymous referee for comments, as well as seminar participants at Pompeu Fabra University, Tilburg University, the International Industrial Organization Conference in Washington, D.C. (May 16–18, 2008), and the European Association for Research in Industrial Economics Conference in Toulouse (September 4–6, 2008). Special thanks go to Hans Friederiszick for his valuable comments and input. Tseveen Gantumur provided excellent research assistance. Financial support from Deutsche Telekom AG is gratefully acknowledged.

[*Journal of Law and Economics*, vol. 55 (February 2012)]
 0022-2186/2012/5501-0007$10.00

(Commission Regulation 2887/2000, Unbundled Access to the Local Loop, 2000 O.J. [L 336] 4–8; Council Directive 2002/19/EC, Access to, and Interconnection of, Electronic Communications Networks and Associated Facilities, 2002 O.J. [L 108] 7–17). The U.S. Telecommunications Act of 1996 (Pub. L. No. 104-104, 110 Stat. 56 [1996]) is another prominent example. In a static environment, mandated access increases competition, which lowers prices and results in a higher consumer surplus. In dynamic settings, the relationship between access regulation and welfare is more complicated. Lower access prices might increase competition in the short term but undermine the incentives of incumbents to invest in the network; higher access prices provide stronger incentives to invest but impede the entrants' use of incumbents' infrastructure and thereby reduce competition (see, for instance, Laffont and Tirole 2000; Newbery 2002).

The regulation/investment trade-off is further complicated by entrants' investment incentives. The role of access regulation with respect to infrastructure investment by entrants is inherently ambivalent (Hellwig 2008): access regulation reduces barriers to entry because entrants do not need to duplicate the existing network, but it also reduces incentives to build new infrastructure because infrastructure can be rented from incumbents at mandated prices. This trade-off is reflected in what is known as facilities-based competition (entrants invest in their own infrastructure) versus service-based competition (entrants rely on regulated access to incumbents' infrastructure).[1] Permitting relatively easy access to incumbents' infrastructure might thus undermine not only incumbents' incentives but also entrants' incentives to invest in infrastructure.[2]

Although it is suggested that easy access limits entrants' incentives to invest in facilities-based competition, this might not be the case for entrants' investment in upgrading incumbents' infrastructure. For example, to enable broadband access to the Internet via an unbundled local loop, an entrant needs to upgrade the local loop as well as invest in the backbone network. Every entry other than the simple reselling of incumbent services thus requires further investment. But these two types of investment differ fundamentally with respect to easy access in that incentives to invest in upgrades might grow out of, and thus be aligned with, easy access provisions (Woroch 1998), in contrast to investments in facilities-based competition (such as in the cable industry), which are not aligned.

These inherent trade-offs have important implications for policy. Many policy makers argue that facilities-based competition affords advantages of variety, low price, and innovation, whereas service-based competition provides only price benefits that result from regulator-promoted access (Cave 2006b). Empirical

[1] Although infrastructure leasing is not needed, interconnection issues among competing networks and bilateral access prices might exist under facility-based competition. For an analysis of regulatory issues in such two-way networks, as opposed to one-way networks in which entrants have access to incumbents' essential facilities, see Valletti (2003).

[2] A variant of this trade-off is emphasized by the so-called ladder hypothesis of investment (Cave and Vogelsang 2003; Cave 2006a, 2006b), also referred to as the stepping stone hypothesis (Rosston and Noll 2002), which suggests that easy access is needed to promote entry and greater infrastructure investment in the long run.

evidence from broadband networks suggests that infrastructure competition between digital subscriber line (DSL) and cable TV providers had a significant positive impact on broadband deployment (Höffler 2007). If facilities-based competition is the ultimate objective of regulators, then incentives for infrastructure investments become a key policy concern.[3]

Empirical assessments need to take into account that incumbents' and entrants' investment incentives are fundamentally different and might not be aligned. This paper establishes an empirical framework for identifying the effect of access regulation on investment by treating incumbents' and entrants' investment decisions as interdependent. Estimating via separate equations the impact of regulation on entrants and incumbents enables us to identify the differential effects on investment incentives between the two as well as the strategic effect of infrastructure investments; it enables us to identify incumbents' and entrants' investments as strategic substitutes or complements.

We further allow for regulation to be endogenous, given that regulatory commitment is highly relevant to long-term investment decisions in regulated (or potentially regulated) industries.[4] The fact that regulatory outcomes, such as unbundling policies and mandated access prices, are subject to political and administrative processes gives rise to a fundamental endogeneity problem. For example, when a regulator's objective is to promote competition to the benefit of the consumer, higher infrastructure investment by incumbents may cause national regulators to provide cheaper access. This, however, will undermine the incumbent's incentives to invest in infrastructure in the first place, giving rise to a regulatory commitment problem. Consequently, regulation needs to be treated as endogenous.

We estimate our econometric model using a comprehensive new data set that covers more than 70 fixed-line operators in 20 EU member states over a 10-

[3] Facilities-based competition might ultimately provide greater benefits in terms of variety, long-term pricing, and innovation. According to the European Commission, "empirical evidence shows that investment and innovation are strongest where there is effective competition between infrastructures. However, there is still no infrastructure-based competition on around 80 percent of the EU's local loops. This means that, ex-ante, regulation continues to play a crucial role in maintaining competition and protecting consumers by setting conditions for access to the incumbent's infrastructure" (Commission Staff Working Document, Summary of the Impact Assessment, 2, SEC [2007] 1473).

[4] Freixas, Guesnerie, and Tirole (1985) were the first to point out that regulatory noncommitment is crucial to the ratchet effect (firms in centrally planned economies underproduce to avoid demanding schemes in the future). More recently, Sidak and Spulber (1996) discuss circumstances under which mandatory unbundling can lead to deregulatory takings by opportunistic regulatory agencies taking a legal perspective. See also Newbery (2002) for an extensive discussion of the problem of regulatory commitment. Crandall (2005, p. 71) shows that U.S. access prices in 2002 were negatively correlated with capital spending of incumbent telecom companies in 1996–99, which suggests that regulators exploit investment ex post (regulatory takings) by reducing the rate at which the investing company is obliged to lease its network to competitors. Duso and Röller (2003) show that the degree of deregulation in the mobile telecommunications industry is explained largely by political variables.

year period.[5] Among the advantages of using this data set to study investment incentives in regulated industries is that it enables us to differentiate between the impact of regulation on incumbents and entrants and to abstract from cable competition to focus on telecom operators, as competition from cable is much less developed in Europe than, for example, in the United States. According to the Organisation for Economic Co-operation and Development (OECD 2007), EU member states typically have low cable penetration rates (for the Czech Republic, the rate is 24 percent; Hungary, 8 percent; Poland, 34 percent; Spain, 57 percent; Sweden, 50 percent; and the United Kingdom, 50 percent), compared to rates near 100 percent in the United States.[6]

Finally, our data set makes use of a new regulatory index based on the number of existing legal measures that facilitate one-way access to incumbents' networks. Other studies use as the regulatory variable a mandated access price such as the local loop unbundling (LLU) rental rate used by Crandall, Ingraham, and Singer (2004).[7] Our indicator of access regulation over access price has two important advantages: it reflects access at different levels of infrastructure (for example, LLU, line sharing, and bitstream access), whereas available access price reflects only LLU, and it is better suited to the context of international comparisons, because it is independent of country-specific costs of building infrastructure. Moreover, given that our index is based exclusively on regulatory measures as opposed to entry or market shares, it represents a significant improvement over the existing OECD index used in other studies (for example, Alesina et al. 2005), which, because it is based in part on the number of entrants, does not distinguish regulation from competition.

The principal empirical findings of our study of the impact of access regulation on investment are as follows:

1. We find empirical support for the differential impact of access regulation on the investment decisions of incumbents and entrants. Access regulation discourages investment by incumbents and individual entrants even as entrants' total investment increases. Moreover, incumbents' investment reacts to entrants' investments. That is, incumbents invest more as entrants' total investment increases.
2. In terms of magnitude, we estimate the overall effect of access regulation on total industry investment in Europe to be a loss of some €16.4 billion over the past 10 years.

[5] The data set was assembled by Competition Analysis, a consulting partner of the European School of Management Technology (Friederiszick, Grajek, and Röller 2008), with the support of Deutsche Telekom.

[6] According to OECD (2009), the average share of cable broadband in the European Union (EU) in 2006 was 20 percent, while it was 53 percent in Canada and the United States. In addition, one observes a sharp decline in cable broadband in the EU, while the same figures in Canada and the United States are stable. This suggests that cable broadband has been losing ground in the EU and was unlikely to be able to exert significant competitive pressure on European telecom operators for the period that we study. For additional robustness checks, see Section 5.

[7] We use the local loop unbundling (LLU) rates to test the robustness of our regulatory index.

3. We find that endogeneity of regulation matters empirically. To be specific, absent controlling for endogenous regulation, we do not find any significant impact of regulation on investment but do identify a significant effect when regulation is permitted to be endogenously determined by the level of infrastructure investment.
4. In terms of regulatory determinants, we find regulatory responses to infrastructure investments to differ between incumbents and entrants. Whereas access regulation is not affected by entrants' investment, regulators permit easier access in response to increased investment by incumbents.

Before proceeding, we would like to emphasize that the focus of this paper is on investment, not welfare. Although the two are related, we do not examine the effect of investment on consumer prices. As a result, our conclusions cannot be used to assess regulation in general welfare terms.

The rest of the paper is organized as follows. In Section 2, we review the literature on investment and regulation in network industries, with a focus on telecommunications. Our econometric model is introduced in Section 3. Data, descriptive results, and instruments are discussed in Section 4. In Section 5, we present our empirical results. We conclude our paper in Section 6.

2. Literature Review

Competition in retail markets can be significantly affected by elements of infrastructure that have natural monopoly properties, with the local loop that connects individual households to the local switch being a prominent example in the telecommunications infrastructure. Duplicating the copper lines in local loops is expensive, at least for the purpose of providing an alternative path for traditional telecommunications service.[8]

In both Europe and the United States, the infrastructure bottleneck was typically resolved by mandating unbundling and sharing of the local loop to provide access to the incumbent's telephone network.[9] Such provisions increase the likelihood of successful entry but reduce the rent that can be earned from infrastructure investments. Because access regulation encourages efficient utilization of infrastructure but has the potential to discourage investment (Valletti 2003), the literature has emphasized a regulatory trade-off between static and dynamic incentives.

Although evidence that access regulation has enhanced static efficiencies abounds, debate persists regarding the impact of access regulation on investments

[8] The natural monopoly features of traditional fixed-line networks are diminishing in importance (Hellwig 2008) as technological progress facilitates the development of alternative networks that deliver similar services and as mobile telecommunications and cable networks offer services that, although imperfect substitutes, nevertheless exert competitive pressure on incumbents.

[9] See Crandall and Waverman (2006) for a recent overview of the industry and regulatory trends on both sides of the Atlantic.

in telecommunications.[10] The Federal Communications Commission (FCC) has recently moved away from access regulation applied to broadband entry (Nuechterlein and Weiser 2005), but access regulation and LLU continue to be the dominant regulatory paradigms in Europe.[11] As a result, while U.S. incumbent operators could circumvent access regulation when investing in broadband networks, the European incumbents did not have this option.

2.1. Impact of Access Regulation on Investment: Theoretical Perspectives

Access regulation has been demonstrated to have a negative impact on investment in a number of theoretical settings, including lowering the net present value (NPV) of incumbents' investments, shifting the risk from entrants to incumbents, and increasing incumbents' risk exposure and, thereby, cost of capital.[12]

The first line of argument emphasizes that rents earned from leasing infrastructure at cost-based prices are lower than monopoly rents realized from owning and selling the infrastructure directly to consumers (Valletti 2003). Under NPV calculations, investments are thus less likely (to be profitable) when access is regulated (Pindyck 2007).

In the context of the considerable uncertainty regarding whether telecommunication infrastructure investment will be adequately reflected in cost-based access charges (Hausman 1997; Jorde, Sidak, and Teece 2000; Haring and Rohlfs 2002; Valletti 2003; Baake, Kamecke, and Wey 2005; Pindyck 2007), incumbents bear all the investment risk under mandated access, while entrants enjoy a risk-free option to lease infrastructure and exploit the regulatory arbitrage between wholesale and retail prices when demand uncertainty is resolved. Cost-based access charges that do not accommodate this risk reduce incumbents' incentives to invest to suboptimal levels (as defined by the NPV). The risk-free option also adversely affects entrants' ex ante incentives to invest in their own infrastructure.

Finally, shifting the risk from entrants to incumbents through cost-based access regulation—if it increases the latter's cost of capital (Jorde, Sidak, and Teece 2000)—will reduce incumbents' ability to invest. The argument is as follows. When uncertainty plays out unfavorably (that is, when demand for telecommunications services turns out to be weak), entrants are more likely to lease local loops. When it plays out favorably and demand is strong, entrants will, because of higher prices for services, be able to afford to roll out their own networks. Because cost-based access charges undercompensate their investment, incumbents' returns will suffer in times of recession and improve during expansion. Investors must be compensated for volatility in incumbents' returns

[10] A large body of literature examines the question of how to set access charges so as to allocate resources efficiently (see, for example, Armstrong, Doyle, and Vickers 1996; Armstrong 2002).

[11] De Bijl and Peitz (2005) provide a recent overview of developments in the telecommunications market in Europe.

[12] See Guthrie (2006) and Armstrong and Sappington (2006) for a comprehensive literature overview.

on assets relative to the market with higher returns on their stocks, which increases the cost of equity.[13]

A number of theoretical contributions, on the other hand, suggest a positive effect of access regulation on investment. As has been pointed out in the literature, a vertically integrated incumbent may not raise a retail competitor's costs if the competitor is more efficient (Rey and Tirole 2007; Sibley and Weisman 1998). Taking this theory a step further, Foros (2004) and Kotakorpi (2006) show that service-based competition—if it increases variety and innovation and, concomitantly, demand—might encourage investment by incumbents. It is crucial, though, that incumbents be able to appropriate profits from increased demand through sufficiently high (possibly unregulated) access charges. The cost-based access charges set by U.S. and EU regulators have been criticized for being too low (Pindyck 2007).[14]

According to the investment ladder hypothesis (Cave and Vogelsang 2003; Cave 2006a), entrants enabled by low access fees to build up an installed base and learn about demand and cost conditions will subsequently be encouraged by rising access charges, together with technological progress and falling costs, to roll out their own networks and commence facilities-based competition.[15] This has been formalized by Bourreau and Dogan (2005, 2006), who show that optimal (from the incumbent's viewpoint) access charges that are rendered prohibitively high when there is no effective threat of facilities-based entry will decrease over time as technological progress renders entry less expensive. Following this strategy would enable an incumbent to forestall facilities-based entry while extracting the maximum rent from entrants.

Finally, access regulation can precipitate a race to provide infrastructure that plays out as increased investment by both incumbents and entrants (Gans and Williams 1999; Gans 2001; Guthrie 2006). The argument goes back to the preemption incentives studied in the context of innovation-timing games (Fudenberg and Tirole 1985; Katz and Shapiro 1987). This race to preempt is particularly relevant to investment in upgrades, such as to broadband Internet provision via DSL. Incumbents who, as a result of the well-known replacement effect, are reluctant to upgrade prior to access regulation will, under access regulation, recognize that the opportunity cost of not upgrading is that an entrant will upgrade.

2.2. Impact of Access Regulation on Investment: Empirical Evidence

Robust empirical analyses of the role of access regulation in investment in rapidly developing telecommunications markets are few and far between.[16] Haus-

[13] Using U.S. data, Ingraham and Sidak (2003) present econometric evidence that supports this hypothesis.

[14] Valletti (2003) and Vogelsang (2003) provide a general overview of access pricing and its possible effect on innovation and investment.

[15] Sappington (2005) argues, however, that entrants' rent-or-make decision might be largely insensitive to access charges and that entrants might be willing to pay rental charges that are higher than cost to constrain retail competition.

[16] See also the recent literature survey in Cambini and Jiang (2009).

man and Sidak (2005) conclude from their descriptive, case-based analyses of telecom markets in Canada, Germany, New Zealand, the United Kingdom, and the United States that mandatory unbundling failed to spur infrastructure investments by incumbents or entrants.

From their finding that low local loop rental rates reduce entrants' facilities-based lines, Crandall, Ingraham, and Sidak (2004) conclude that unbundling decreases facilities-based competition. Furthermore, from estimating the relationship between access price and incumbents' infrastructure investment, Chang, Koski, and Majumdar (2003) conclude that low access prices spur investment. Our study estimates both incumbents' and entrants' investments and accommodates the strategic interaction between them.

Studies of the impact of regulation on telecommunications investment that aggregates the fixed-line and mobile segments (Li and Xu 2004; Alesina et al. 2005) find a positive impact of entry liberalization and competition on total investment but cannot draw a conclusion about individual segments with quite different competitive landscapes.[17] Studies of broadband penetration (Wallsten 2005, 2006), an important indicator of a telecommunications market's degree of development as it captures both supply- and demand-side factors, report a negative impact of LLU on broadband. Because it examines investments of individual telecom operators, our study enables us to derive policy conclusions and test in more detail a number of predictions.

Finally, most of these studies acknowledge the problem of endogeneity with respect to regulation, but few tackle it econometrically.[18] Our data enable us to employ a set of unique instruments, including political and geographic variables, to accommodate endogeneity in regulation.

3. Econometric Model

To analyze the effect of regulation on investment, we consider a situation of one incumbent, several entrants, and a regulator. Our specification allows for the simultaneous determination of the level of regulation with the entrants' and incumbents' levels of infrastructure. In other words, regulation has an effect on incumbents' and entrants' investment decisions, which in turn affect regulation. Firms decide how much capacity to add to the existing infrastructure to offer an additional service to customers.[19]

We specify the regulation equation as follows:

[17] The most important difference is the economic viability of pure facilities-based competition, which is viable in mobile telecommunications with two or more parallel network infrastructures in many geographic markets but questionable in fixed-line telecommunications.

[18] Li and Xu (2004), which applies instrumental variables (IV) techniques, is an exception.

[19] An upgrade of the existing public switched telephone network lines to offer broadband Internet service based on digital subscriber line technology, for example.

$$\Delta \text{Reg}_{i,t} = \alpha_i^{\text{R}} + \lambda_t^{\text{R}} + \beta^{\text{R}} \text{Reg}_{i,t-1} + \gamma^{\text{R}} \text{IncInf}_{i,t} + \delta^{\text{R}} \Sigma \text{EntInf}_{i,t} + \mathbf{X}_{i,t}^{\text{R}} \boldsymbol{\theta}^{\text{R}} + \eta_{i,t}, \quad (1)$$

where Reg_{it} is the intensity of regulation in a given national market i in year t, $\text{IncInf}_{i,t}$ is the infrastructure stock of the incumbent, $\Sigma\text{EntInf}_{i,t}$ is the sum of the stock of entrants' infrastructure, and Δ is the change from year $t-1$ to year t. The term $\boldsymbol{X}_{i,t}^{\text{R}}$ is a set of control variables. The superscript R denotes variables and coefficients specific to the regulation equation.

Equation (1), our policy equation, endogenizes access regulation by making the intensity of regulation ($\text{Reg}_{i,t}$) depend on the stock of infrastructure of both incumbents ($\text{IncInf}_{i,t}$) and entrants ($\Sigma\text{EntInf}_{i,t}$). We can thus investigate empirically whether a regulator is responding differently to investments by incumbents and entrants. When a regulator is more responsive to incumbents' infrastructure, then $\gamma^{\text{R}} > \delta^{\text{R}}$.

The incumbents' investment is given by

$$\Delta \text{IncInf}_{i,t} = \alpha_i^{\text{I}} + \lambda_t^{\text{I}} + \beta^{\text{I}} \text{IncInf}_{i,t-1} + \gamma^{\text{I}} \Sigma \text{EntInf}_{i,t} + \delta^{\text{I}} \text{Reg}_{i,t} + \mathbf{X}_{i,t}^{\text{I}} \boldsymbol{\theta}^{\mathbf{I}} + \varepsilon_{i,t}, \quad (2)$$

where $\boldsymbol{X}_{i,t}^{\text{I}}$ is a set of control variables. The superscript I denotes variables and coefficients specific to equation (2), which stipulates that incumbents' investment ($\Delta\text{IncInf}_{i,t}$) depends on the intensity of regulation ($\text{Reg}_{i,t}$) and the sum of the stock of entrants' infrastructure ($\Sigma\text{EntInf}_{i,t}$). Parameter δ^{I} is the impact of regulation on incumbents' investments, and parameter γ^{I} is the strategic effect of entrants' investment on incumbents' investment. Note that $\gamma^{\text{I}} > 0$ is evidence that incumbents' and entrants' investments are strategic complements, and $\gamma^{\text{I}} < 0$ is evidence that their investment decisions are substitutes. Since we use the logarithm of infrastructure stock, the results of the estimates are interpreted as percentage changes.

We model the sum of entrants' investment as follows:

$$\Delta \Sigma \text{EntInf}_{i,t} = \alpha_i^{\text{E}} + \lambda_t^{\text{E}} + \beta^{\text{E}} \Sigma \text{EntInf}_{i,t-1} + \gamma^{\text{E}} \text{IncInf}_{i,t} + \delta^{\text{E}} \text{Reg}_{i,t} + \mathbf{X}_{i,t}^{\text{E}} \boldsymbol{\theta}^{\text{E}} + \zeta_{i,t}, \quad (3)$$

where $\boldsymbol{X}_{i,t}^{\text{E}}$ is a set of control variables and superscript E denotes variables and coefficients specific to equation (3), which permits entrants' investment decisions ($\Sigma\text{EntInf}_{i,t}$) to depend on the intensity of regulation ($\text{R}_{i,t}$) and the stock of incumbents' infrastructure ($\text{IncInf}_{i,t}$). Parameter δ^{E} measures the impact of regulation on entrants' investment decisions. When $\delta^{\text{E}} < \delta^{\text{I}}$, the impact of regulation on investment decisions is greater for incumbents than for entrants. Analogous to equation (2), when $\gamma^{\text{E}} > 0$ ($\gamma^{\text{E}} < 0$), incumbents' and entrants' investments are strategic complements (substitutes). Finally, we assume the errors $\eta_{i,t}$, $\varepsilon_{i,t}$, and $\zeta_{i,t}$ to be independently and identically distributed.[20]

[20] We report standard errors, which are robust to heteroskedasticity.

Note that by summing over all entrants in equations (1)–(3), we assume that regulators and incumbents react to aggregate investment by entrants. In other words, we treat de novo entry and investment by existing entrants analogously. In particular, we assume no strategic interaction between entrants because entrants' investments do not depend on each other in equation (3). This set of assumptions is consistent with the regional-based entry pattern observed in fixed-line telecommunications (Greenstein and Mazzeo 2006). When each entrant chooses a different region of operations, entrants can be assumed to behave strategically to regulation and incumbents' investments in that region only.

Later we also estimate a variant of equation (3) at the individual entrant level. Examining individual investments sheds more light on whether entry is facilities based or service based. Facilities-based entry is likely to involve substantially greater investment per entrant, while service-based entry requires less investment per entrant. Moreover, estimating equation (3) at the individual entrant level enables us to test for strategic interaction between entrants.

Note also that equations (1)–(3) include country dummies, year dummies, and lagged dependent variables.[21] Accordingly, the α_i terms capture country-specific effects, such as the cost of rolling out infrastructure, and the λ_t terms control for common time trends, such as possible stock market bubbles. The dynamic adjustments captured by the β terms act as an exogenous constraint on how quickly the players can deploy (or withdraw) the infrastructure. If all β terms are equal to -1, then all adjustment happens in one period, and the equations (1)–(3) become fully static. If, however, the β terms are between 0 and -1, the best response involves gradual changes to infrastructure over multiple periods, whereas the long-term level is given by the current level divided by $-\beta^{I}$ ($-\beta^{E}$) in the case of the incumbent (entrant). Moreover, we allow the regulation to follow a similar adjustment process as the infrastructure level while bearing in mind that a gradual adjustment to the regulatory intensity may be easier to facilitate than a drastic change.[22]

The aforementioned structural equations (1)–(3) can be thought of as linearized first-order conditions of a static investment game between the operators and the national regulator. In this game, each operator and regulator chooses simultaneously the level of infrastructure and regulation, respectively, as a best response to the choices of other players. The identification of coefficients on the endogenous variables in equations (1)–(3) is achieved through a set of exclusion restrictions. As described above, in each of the three equations we include that equation's own lagged dependent variables but not the lagged dependent variables

[21] That all dependent variables are in differences enables us to interpret the infrastructure equations as investment equations. This specification is equivalent to the one with levels (or stocks) as the dependent variable.

[22] Alternatively, one could postulate that investment reacts to regulation with a lag. Moreover, investment may vary with changes in regulatory policy as opposed to the level of regulation. To test these specifications, we reestimated our model with these two different functional specifications, and our results were not rejected by them. We do not report the estimation results of these alternative specifications but will provide them on request.

from the other equations. Moreover, we put further restrictions on the control variables in vectors $\boldsymbol{X}^{R}$, $\boldsymbol{X}^{I}$, and $\boldsymbol{X}^{E}$. More details on the exclusion restrictions follow in Section 5.

Finally, note that we include both lagged dependent variable and country-specific effects. Consistent estimation of our equations requires panel data with a sufficiently long time dimension. Because Monte Carlo simulations of a dynamic panel data model such as ours indicate that our sample size might not be sufficiently large (Judson and Owen 1999), we investigate the potential bias by applying a corrected estimator (Kiviet 1995; Bruno 2005).

4. Data, Descriptive Results, and Instruments

The data used in our estimations covers more than 70 fixed-line telecom operators in 20 EU member states during 1997–2006.[23] Our sample thus spans a period from before the official liberalization of the European telecommunications market on January 1, 1998, until the successful implementation of the EU telecommunications regulatory framework by all member states.[24] The Amadeus database is the main source of firm-level accounting data used to calculate the stock of infrastructure,[25] and Plaut Economics (Zehnhäusern et al. 2007) is the source of the regulation index. Additional data sources include the Osiris database, the World Bank's World Development Indicators database, and the Manifesto Project database[26] (Klingemann et al. 2006). Table 1 summarizes the variable definitions and identifies the sources. Descriptive statistics are reported in Table 2.

For infrastructure stock, we will use firms' tangible fixed assets deflated by the producer price index (PPI) for telecom equipment. This allows us to calculate infrastructure investments as the year-to-year change in stocks. Tangible fixed assets include land, buildings, plants, machinery, and equipment and therefore constitute a rather broad measure of infrastructure.[27] While other studies use

[23] The following countries (EU15) are in our data set: Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Portugal, Sweden, and the United Kingdom. The data set also includes the following EU12 countries (new member states after the 2004 and 2007 accessions): Bulgaria, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, and Slovenia.

[24] The eleventh report on the implementation of the telecommunications regulatory framework was the first to state that member states have done most of the necessary work to implement the framework (Communication from the Commission, European Electronic Communication Regulation and Markets 2005, COM [2006] 68 final [February 20, 2006]).

[25] Bureau van Dijk, Amadeus (http://www.bvdinfo.com/Products/Company-Information/International/Amadeus).

[26] Bureau van Dijk, Osiris (http://www.bvdinfo.com/Products/Company-Information/International/Osiris); World Bank, World Development Indicators (http://data.worldbank.org/data-catalog/world-development-indicators); WZB, Manifesto Project (https://manifesto-project.wzb.eu).

[27] Another issue is that of mergers and acquisitions (M&As), which represent a change in asset ownership rather than new infrastructure investment. To check robustness, we include in our estimation data on firms' M&A activity from the SDC Platinum M&A database (Thomson Reuters, SDC Platinum [http://thomsonreuters.com/products_services/financial/financial_products/a-z/sdc]). Given that the M&A variable is not significant in these estimations, we do not report the results but will provide them on request.

Table 1
Description of Variables

Variable	Description	Source
IncInf	Incumbent's infrastructure stock measured as tangible fixed assets (year 2000 € millions)	Amadeus, Osiris
EntInf	Entrant's infrastructure stock measured as tangible fixed assets (year 2000 € millions)	Amadeus, Osiris
ΣEntInf	Total (aggregated at the national level) entrants' infrastructure stock measured as tangible fixed assets (year 2000 € millions)	Amadeus, Osiris
Reg	Index of access regulation intensity; higher values indicate higher intensity of regulation	Plaut Economics
NoEnt	Dummy variable set equal to one if there are no entrants in the market and zero otherwise	Amadeus, Osiris
GDP	Per capita gross domestic product (year 2000 €)	World Bank's WDI
RegNeighbor	Average index of access regulation intensity in neighboring markets	Plaut Economics
Gov	Government's attitude toward regulation; higher values indicate more favorable position	Manifesto Project
Rile	Government's ideological position on the right-left scale; higher values indicate more right-wing position	Manifesto Project
Europe	Government's attitude toward European integration; higher values indicate more favorable position	Manifesto Project

Sources. Bureau van Dijk, Amadeus (http://www.bvdinfo.com/Products/Company-Information/International/Amadeus; Bureau van Dijk, Osiris (http://www.bvdinfo.com/Products/Company-Information/International/Osiris); Plaut Economics (Zehnhäusern et al. 2007); World Bank, World Development Indicators (WDI) database (http://data.worldbank.org/data-catalog/world-development-indicators); WZB, Manifesto Project (https://manifesto-project.wzb.eu).

transmission lines as means of measuring infrastructure (Chang, Koski, and Majumdar 2003; Crandal, Ingraham, and Singer 2004), the advantage of our measure is that it allows us to study the strategic behavior of both the incumbents and the entrants in a number of geographic markets over a long period. Our infrastructure measure corresponds to the geographic markets, which we define as EU member states, and operators with multinational presence. With only a few exceptions, the tangible fixed assets that we measure are from the fixed-line segment of the telecommunications markets.[28] The list of operators in our sample, together with a detailed description of how the infrastructure measure was broken down to match the geographic and the product markets, is reported in the Appendix. The average stock of incumbents' and entrants' telecom infrastructure and the average number of entrants across time are shown in Figure 1.

The regulation variables in our analysis are from Plaut Economics (Zehnhäusern et al. 2007). The Plaut regulatory index provides detailed, comprehensive information on different regulatory measures in the telecom sector for all 27 EU countries during 1997–2006. We use five subindices related to access to

[28] In 10 of more than 70 cases, we were not able to separate the operator's fixed-line network from the mobile telephone infrastructure. Country-specific fixed effects, which we use in all equations, control for this omission to some extent.

Table 2
Descriptive Statistics

Variable	Mean	SD	Min	Max
IncInf	2,350.1	3,597.1	.051	19,787.3
EntInf	140.0	250.8	.010	1,563.9
ΣEntInf	462.6	1,020.0	0	7,008.4
Reg	.45	.29	.14	.86
NoEnt	.24	.43	0	1
GDP	12,425.4	8,379.9	1,415.2	29,067.0
RegNeighbor	.44	.26	.14	.78
Gov	1.50	1.14	0	4.47
Rile	3.94	9.19	−12.65	28.47
Europe	1.98	1.56	−.78	6.25

incumbents' infrastructure—specifically, the existence of accounting separation obligation, regulation regarding full unbundling, line sharing, bitstream access, and subloop unbundling of fixed-line incumbents' local loops.[29] Our measure of access regulation intensity is then an average of these binary subindices that reflects the extent of mandated sharing of incumbents' infrastructure.

Figure 2 shows the development of all five subindices that enter our measure of access regulation over the sample period. The EU average of each of the five subindices reflecting the share of EU countries that adopted each of the regulatory measures is shown on the vertical axis. Accounting separation is the most widely adopted measure, especially in the early years. This is intuitive because an appropriate cost-accounting system is necessary to support price controls of access to an incumbent's infrastructure.[30] The other four regulatory measures grant access to entrants at various levels of the incumbent's infrastructure. At one extreme, full unbundling gives entrants full control of the local loop. In particular, it allows for voice service and, after upgrading, broadband service via DSL technology to be offered. At the other extreme, bitstream access allows entrants to offer broadband service via local loops upgraded by the incumbent. Line sharing is an intermediate measure in that it gives entrants access to the part of the local loop's spectrum that can be used for broadband, but entrants need to install the necessary upgrade themselves, and subloop unbundling means that only the last part of the local loop is unbundled. Figure 2 suggests that capital-intensive access measures (full unbundling and line sharing) are typically introduced earlier than less capital intensive bitstream access. This pattern is confirmed in the individual

[29] The indicators that enter our regulatory index for the fixed-line segment correspond to keys 12 through 16 of the Plaut index.

[30] The mandated access charges in Europe were established by national regulators, and the detailed rules varied from country to country. However, the overarching principle was the method of cost recovery allowing a reasonable rent on capital employed (Council Directive 2002/19/EC, Access to, and Interconnection of, Electronic Communications Networks and Associated Facilities, 2002 O.J. [L 108] 7–17)—that is, the rate-of-return regulation—which is in contrast to situation in the United States, where a particular form of incentive regulation (total element long-run incremental cost, or TELRIC) was imposed.

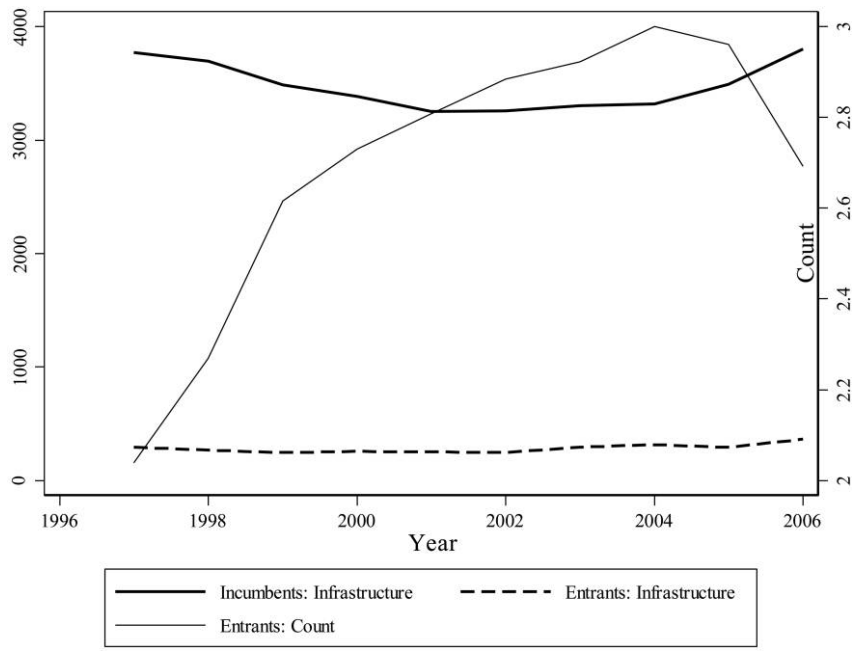

Figure 1. The average stock of fixed-line telecom infrastructure and the average number of entrants per European Union member state in the sample.

country data: only two European countries (Belgium and Spain) phased in the regulatory measures in the opposite order, and two others (France and the United Kingdom) introduced them simultaneously. Thus, an increasing overall measure of access regulation comprising these five measures can be interpreted as rendering entry easier, because it allows national regulators to set better informed cost-based access charges, it allows entrants to pick and choose an optimal level of access that is based on demand and the cost of infrastructure, and it allows for less infrastructure investment per connected customer.

Figure 3 reports the evolution of regulation in the European telecom sector, as represented in our analysis, over the past 10 years. Whereas the old EU member states (EU15) experienced growing regulatory intensity in the fixed-line segment, which leveled off in 2002, no substantial measures to promote entry into fixed-line telephony were introduced in the new member states (EU12) until the eve of the 2004 EU accession. Because it will be used for the construction of the geographical instruments, the distinction between EU15 and EU12 is important to keep in mind.

Tables 1 and 2 also present the control variables used in equations (1)–(3). Gross domestic product per capita is included in our estimations to control for

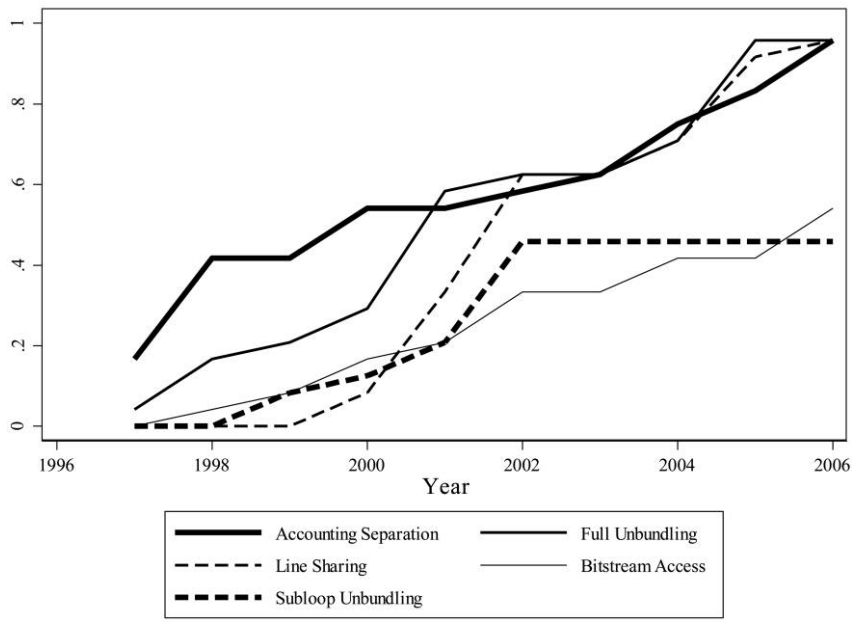

Figure 2. Subindices of access regulation in European Union fixed-line telecom markets.

changes in demand for telecommunication services. The no-entry indicator (NoEnt) equals one when there is no entrant infrastructure in a given market. Otherwise, it equals zero. The term NoEnt picks up any effects when infrastructure stock equals zero.[31]

The other control variables characterize aspects of national access regulation. The term RegNeighbor is a geographical instrument that captures the average level of entry regulation in neighboring markets. Our definition of neighbor is not geographical but rather relates to belonging to the same cohort (EU15 or EU12), given that the level of regulation varies substantially between these two groups (Figure 2). Consequently, because Germany and Poland belong to different cohorts (EU15 and EU12, respectively), they do not constitute neighboring markets even though they are contiguous geographic neighbors. Variables based on party manifestos to measure political positions of governments include overall policy positions of governments in terms of right versus left (Rile), favoring market regulation and government presence in markets (Gov), and attitude

[31] It also helps us to estimate equations (1)–(3) in logs, as we do not have to drop observations. When entrants' infrastructure stock equals zero, we set entrants' infrastructure at the smallest positive value in the sample.

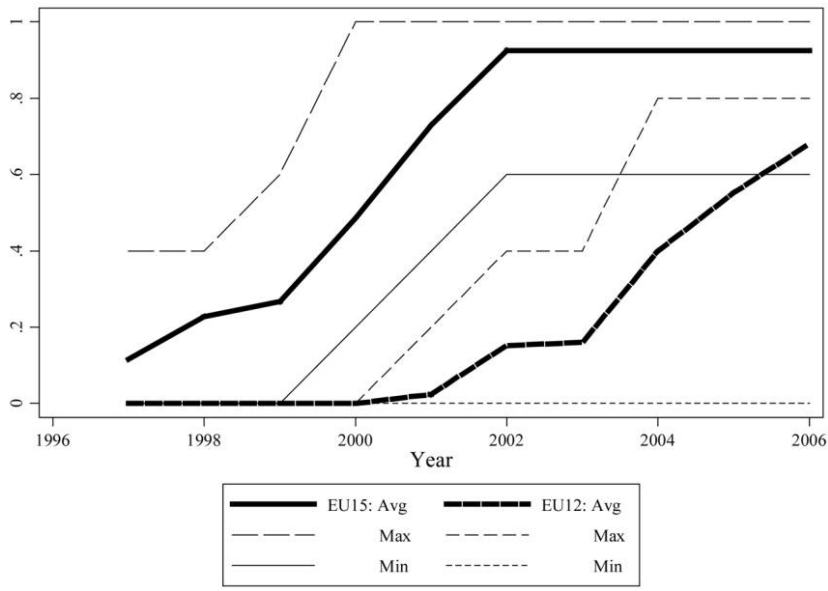

Figure 3. Index of access regulation in European Union (EU) fixed-line telecom markets: the 15 old EU states (EU15) versus the 12 new EU states (EU12).

toward European integration (Europe).[32] We do not have any priors regarding the government's overall policy position, but we expect governments that favor regulation and European integration to be more inclined to implement mandated sharing of telecom infrastructure as prescribed in the EU regulatory framework. We also expect regulation to be spurred by developments in neighboring markets that exert pressure on national regulators. In other words, we expect to see a regulatory catching-up effect among the member states.

5. Empirical Results

We estimate equations (1)–(3) by first using ordinary least squares (OLS) and then instrumental variables (IV) methods. In each equation, all explanatory variables of the model are used as instruments. The OLS and IV results are reported in Tables 3 and 4, respectively. Country dummies (α_i terms) and year dummies (λ_t terms) are not reported, for brevity.

The identification of coefficients on the endogenous variables in equations

[32] Government's position is defined as the weighted average score of parties in the government, with the weights being determined by the proportion of parliamentary seats held by each party. In election years, government position is taken as the average position of two consecutive governments weighted by number of months in office.

Table 3
Ordinary Least Squares Estimation Results

	Regulation	Incumbent	Entrants
Dependent variable	ΔReg_t	$\Delta \log(IncInf_t)$	$\Delta \log(\Sigma EntInf_t)$
Dynamic effects:			
Reg_{t-1}	−.689** (.090)		
$\log(IncInf_{t-1})$		−.716** (.132)	
$\log(\Sigma EntInf_{t-1})$			−.794** (.081)
Simultaneity:			
Reg_t		−.094 (.192)	.479 (.342)
$\log(IncInf_t)$	.033** (.013)		−.186* (.082)
$\log(\Sigma EntInf_t)$	−.004 (.009)	.034 (.036)	
Controls:			
$NoEnt_t$	.031 (.075)	−.068 (.325)	−7.088** (.914)
$\log(GDP_t)$	−.208* (.099)	.068 (.404)	−.581 (.541)
$RegNeighbor_t$	.669** (.111)		
Gov_t	−.073** (.023)		
$Rile_t$	.004** (.001)		
$Europe_t$	.019 (.012)		
N	120	129	139
Serial correlation	.04	.33	−.03

Note. Robust standard errors are in parentheses. Coefficients on country and year dummies are not reported.
* Significant at the 5% level.
** Significant at the 1% level.

(1)–(3) rests on a set of exclusionary restrictions. First, as can be read from Table 4, all three endogenous variables are assumed to depend on their own lagged levels but not on the lagged levels of other endogenous variables. As indicated previously, the lagged levels of the dependent variables are meant to capture the exogenous constraint on the speed with which the best response investment can be achieved. This assumption is consistent with the static nature of the game played between the regulator and the firms that we consider. Second, we assume that the set of political variables, Rile, Gov, and Europe, and the extent of regulation in neighboring markets, RegNeighbor, directly affect domestic regulation but are not related to the domestic investment in the telecom infrastructure.

We perform a number of specification tests, including testing exogeneity and the strength of our instruments in the IV regressions. As reported in Table 4, Hansen *J*-statistics are insignificant, which suggests that the overidentifying restrictions are valid.[33] The regressions-based tests (Wooldridge 2002, p. 176) accept no serial correlation in the error term, which is important for the consistency of our estimates, as we have lagged dependent variables in the model and use as instruments, among others, lagged values of endogenous variables. Finally, *F*-tests for our instruments in the first-stage regressions (not reported) are significant at the 1 percent level for all endogenized variables, with the exception of

[33] Regulation equation (1) is exactly identified, so the Hansen *J*-statistic cannot be computed.

Table 4
Instrumental Variable Estimation Results

	Regulation	Incumbent	Entrants
Dependent variable	ΔReg_t	$\Delta \log(IncInf_t)$	$\Delta \log(\Sigma EntInf_t)$
Dynamic effects:			
Reg_{t-1}	−.685** (.094)		
$\log(IncInf_{t-1})$		−.676** (.149)	
$\log(\Sigma EntInf_{t-1})$			−.817** (.080)
Simultaneity:			
Reg_t		−.975* (.458)	1.195^{+} (.634)
$\log(IncInf_t)$	.157* (.076)		−.407 (.433)
$\log(\Sigma EntInf_t)$	−.002 (.021)	.179^{+} (.098)	
Controls:			
$NoEnt_t$	.084 (.165)	1.172 (.798)	−7.351** (1.024)
$\log(GDP_t)$	−.182 (.148)	−.360 (.650)	−.300 (.743)
$RegNeighbor_t$	.661** (.125)		
Gov_t	−.080** (.024)		
$Rile_t$	.002 (.002)		
$Europe_t$	.032* (.015)		
N	110	110	110
Hansen *J*		3.42 (3)	4.26 (3)
Serial correlation	−.03	.12	−.18

Note. Robust standard errors are in parentheses. Coefficients on country and year dummies are not reported.
$^{+}$ Significant at the 10% level.
* Significant at the 5% level.
** Significant at the 1% level.

incumbent infrastructure, for which the test is significant at the 14 percent level. These test results support our instruments, albeit somewhat more weakly for the incumbent infrastructure variable.[34]

We also test for endogeneity of regulation and investment decisions, a crucial part of the analysis often absent from previous studies. Comparing the OLS to the IV estimates reveals significant differences in the coefficient estimates (see Tables 3 and 4). A Hausman specification test rejects that the difference in coefficients is not systematic at the 1 percent confidence level for equations (1)–(3), confirming that endogeneity matters empirically. As can be seen in Table 3, if we do not account for endogeneity of regulation, we find no significant impact of regulation on investment, whereas if we allow regulation to be endogenously determined by level of infrastructure investment, we find a significant effect (Table 4). In sum, investment in regulated network industries is subject to significant endogeneity bias that must be accounted for to understand the relationship between access regulation and investment.[35]

[34] Results of the first-stage regressions are available from the authors on request.

[35] We also tested, using ordinary least squares regressions, the bias of estimating the dynamic panel data model with fixed effects (also referred to as the least-squares dummy variable [LSDV]). Applying a corrected LSDV estimation (Kiviet 1995; Bruno 2005), we found little difference from our estimates; coefficients on the lagged dependent variable were slightly lower in magnitude, and the other coefficients were virtually unchanged (these results are available on request). We therefore conclude

A number of interesting insights emerge from a review of the estimates in Table 4. One is the importance of dynamic adjustment effects, because the lagged infrastructure and regulation variables are statistically significant and economically relevant, which suggests that there are both short-term and long-term effects: a short-term adjustment of infrastructure levels will be followed by future adjustments until the desired level of infrastructure is reached. It is interesting to note that there is also evidence of a dynamic regulatory process—that is, with regulatory changes occurring as a gradual process rather than as a one-shot affair.

The estimates of equation (1) presented in Table 4 imply that regulators do respond to investment by firms, as regulation increases in the stock of incumbents' infrastructure (γ^R is positive). This finding suggests that regulators are subject to a commitment problem: when the level of incumbents' infrastructure stock is high, national regulators tend to grant easier access, which is a disincentive for incumbents to invest in the first place.[36] Regulatory intensity is not affected, however, by entrants' infrastructure stock (δ^R is insignificant). We thus find evidence in our data that regulators respond quite differently to incumbents' and entrants' infrastructure investments.[37]

The results of equations (2) and (3), presented in Table 4, indicate that the effect of regulation on the investment decisions of incumbents and entrants is quite different. Controlling for endogeneity, we find that an increase in regulatory intensity decreases incumbents' investment but increases total investment across entrants. To be specific, our estimate suggests that increasing regulatory intensity by .5, which roughly corresponds to the average change in the regulatory regime in EU15 between 1997 and 2002, reduces incumbents' infrastructure stock by approximately 49 percent, and by as much as 72 percent in the long run.[38,39] The same change in regulation increases entrants' total infrastructure stock by approximately 60 percent, and by as much as 73 percent in the long run. These results suggest that the impact of regulatory intensity on investment is signifi-

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that the endogeneity bias is much more important and ignore the other bias. In doing so, we might underestimate the long-term effects of explanatory variables in our model.

[36] Note that we interpret our findings along the time-series dimension because all equations that we estimate include country-specific fixed effects. Hence, a possible effect that national authorities impose more stringent access regulation on large, rather than growing, incumbents is then absorbed by the fixed effects.

[37] Moreover, we test whether regulation depends positively on the gap between incumbents' and entrants' infrastructure levels. This hypothesis can be formulated as $(\gamma^R - \delta^R)/2 > 0$. Using the estimates on standard errors in Table 4, we do not reject the gap hypothesis at the 10 percent level. One possible drawback of our regulatory index is that it aggregates the five regulatory measures symmetrically. To address this issue to some extent, we reestimated our model, including each of the five regulatory measures separately. The individual results for the five submeasures are in line with all our main findings from the aggregate model, albeit slightly less so in the case of accounting separation. These results are available on request.

[38] With the dependent variable in logarithms, the effect is in percentages.

[39] Recall that the long-term effect of an increase in regulation on incumbents' infrastructure stock can be calculated from equation (2) as $-\delta^I/\beta^I$, which is $-.4875/.676 \approx .72$.

cantly different for incumbents and entrants, which confirms the validity of our empirical approach of treating incumbents and entrants differently.[40,41]

Taking this a step further, we note that in Table 4 the impact of entrants on incumbents' infrastructure investments is positive (γ^I is estimated at .179 and is significant at the 10 percent level), which indicates that the respective investments are strategic complements. In other words, when entrants invest more, so do incumbents. This strategic effect reduces the negative impact of regulation on investment incentives. The estimates in Table 4 further suggest that although tighter regulation has a direct negative effect on incumbents' investment incentives, it also increases entrants' infrastructure investment, which in turn has a positive impact on incumbents' investment through strategic complementarity.[42] Taking this into account, we find that increasing the regulation index by .5 reduces incumbents' infrastructure stock by approximately 47 percent over the long term. In other words, the negative impact of regulation on incumbent's investment incentives is only partially compensated by strategic complementarity. On the other hand, the strategic effect boosts investment by entrants. Although not statistically significant, the strategic effect increases entrants' infrastructure investment to 96 percent over the long term. In terms of monetary impact, the additional 96 percent of entrants' infrastructure stock and 47 percent loss of incumbents' infrastructure stock correspond to €444 million and €1.1 billion per EU member state, respectively.[43] This adds up to some €16.4 billion in lost infrastructure investment for the European Union as a whole, which corresponds to almost 23 percent of the infrastructure stock.

An important assumption is that we abstract from cable competition to focus on telecom operators, despite the fact that cable companies have penetration rates in excess of 50 percent in some countries in our sample and have proved to be a vibrant source of telephone competition in some countries, including the United States. To test this assumption, we followed two approaches. First, to test whether cable has an impact on our estimates, we add the national shares of households covered by cable. Second, we exclude EU countries with a cable

[40] To test whether the same regulatory index results in significantly different prices across countries, we reestimated our model incorporating LLU rates. The following specifications were estimated: (1) to test whether LLU prices change the effect of Reg, we add the LLU rate as well as an interaction term between Reg and LLU, and (2) we vary the coefficient on Reg by interacting Reg with a dummy denoted LLU_high, which indicates whether the LLU rental rate is above the sample average. The resulting estimates for the LLU variables turned out not to be significant in either specification, thus suggesting that the implementation of the various access requirements in terms of prices do not vary across the EU to the extent that our main results are affected. The detailed results are available on request.

[41] Table 2 suggests differences in the scale at which the firms operate, which could have an effect of regulation on investment (and vice versa). To test this, we reestimated our model, including an interactive term of the regulatory index with the incumbent's and entrants' infrastructures. The interaction terms turned out not to be statistically significant. It thus does not appear that our results are driven by scale effects as measured by infrastructure. The detailed results are available on request.

[42] Note that strategic complementarity does not work the other way around—that is, from incumbents to entrants (γ^E is negative and not significant).

[43] This is calculated at the sample mean, assuming that regulation is exogenous.

share of broadband in excess of 30 percent in 2006. Note that under the assumption that cable reflects investment targeting TV rather than the telecom services, this variable is exogenous in our model, which justifies using it as a control. The estimation results of the first approach indicate that cable had no significant effect in either of the equations and did not significantly change any of the other parameter estimates. With regard to the second approach, our main results were not significantly changed either, although the statistical significance was lower because of the restricted sample size. In sum, we maintain that cable competition does not significantly alter the outcomes in the European telecom markets.[44]

Finally, the impact of the control variables is generally as expected. In Table 4, regulation in neighboring markets, RegNeighbor, has a significant impact on national regulation, which reflects regulatory catching up in the EU. A positive attitude of government toward European integration, Europe, increases regulatory intensity in a given national market, whereas the government attitude toward regulation, Gov, has, somewhat surprisingly, a significant negative impact. One explanation for the latter finding is that Gov measures attitude toward old-style regulation of monopoly markets. Governments' attitude toward access regulation in telecommunications markets might be quite different, even opposite, because it emphasizes generating competition within the market. Governments' ideological position, Rile, and gross domestic product are significant in the OLS estimation (Table 3) but not in the IV estimation. Finally, the negative coefficient on NoEnt in the entrants' equation (3) controls for zero infrastructure levels.

Note that we have thus far investigated only the impact of access regulation on total investment summed over entrants, not the extent to which regulation affects entrants' individual investments. An increase in total infrastructure investment could obviously be due to greater numbers of entrants, larger investments by individual entrants, or both. Examining individual investments sheds light on facilities-based versus service-based entry. Because facilities-based entry is likely to involve substantially more investment, less investment per entrant would be expected in the case of service-based entry. To test for this in our data, we estimate equation (3) at the firm level as follows:[45]

$$\begin{aligned}\Delta\mathrm{EntInf}_{j,i,t} = {} & \alpha_i^{\mathrm{E}} + \lambda_t^{\mathrm{E}} + \beta^{\mathrm{E}}\mathrm{EntInf}_{j,i,t-1} + \gamma^{\mathrm{E}}\mathrm{IncInf}_{i,t} \\ & + \delta^{\mathrm{E}}\mathrm{Reg}_{i,t} + \mathbf{X}_{i,t}^{\mathrm{E}}\boldsymbol{\theta}^{\mathrm{E}} + \xi_{j,i,t},\end{aligned} \tag{3'}$$

where $\Delta\mathrm{EntInf}_{j,i,t}$ denotes infrastructure investment by individual entrants j in market i at time t. The results of reestimating equation (3′) using OLS and IV regressions are reported in Table 5. As can be seen, the Hansen J-statistic does not reject exogeneity of the instruments; the Hausman specification test (not reported) suggests that the difference in coefficients is systematic.

[44] These results are available on request.

[45] Unfortunately, no data broken down by facilities-based versus service-based infrastructure investment are available.

Table 5
Estimation Results for Individual Entrants, by Regression Method Used

	OLS	IV
Dynamic effects:		
Reg_{t-1}		
$\log(IncInf_{t-1})$		
$\log(EntInf_{t-1})$	−.075* (.030)	−.078* (.032)
Simultaneity:		
Reg_t	−.935^{+} (.556)	−1.942^{+} (1.103)
$\log(IncInf_t)$	−.115 (.230)	−1.492^{+} (.883)
$\log(\Sigma EntInf_t)$		
Controls:		
$NoEnt_t$		
$\log(GDP_t)$	.672 (.799)	.699 (1.252)
$RegNeighbor_t$		
Gov_t		
$Rile_t$		
$Europe_t$		
N	237	192
Hansen *J*		4.97 (4)
Serial correlation	.01	.05

Note. The dependent variable is $\Delta\log(EntInf_t)$. Robust standard errors are in parentheses. Coefficients on country and year dummies are not reported. OLS = ordinary least squares; IV = instrumental variables.
$^{+}$ Significant at the 10% level.
* Significant at the 5% level.

Comparing the coefficients' estimates of equations (3) and (3′), we see that most results remain unchanged.[46] The estimated coefficient on the lagged dependent variable is negative and highly significant as well as much smaller than that in Table 4, which suggests that the dynamics are more persistent at the individual entrant level than at the market level. As before, incumbent infrastructure has a negative impact on entrants, although it is now significant in the IV estimation (γ^E is estimated at −1.492 and is significant at the 10 percent level). More important, however, the impact of regulation on an individual entrant's investment is negative (although statistically significant only at the 10 percent level), which suggests that entrants' total investment increases even as investment by individual entrants declines with regulation that eases access. In other words, easier access pushes entrants toward service-based competition.[47] This finding is consistent with the view that the EU regulatory framework is not providing effective incentives to move toward facilities-based competition.

[46] We also tested the strategic interactions between entrants by including total entrants' stock of infrastructure in the disaggregated equation (3′). That this variable turned out never to be significant corroborates our assumptions. The results are available on request.
[47] This result is consistent with Friederiszick, Grajek, and Röller (2008), which estimates a similar model without the strategic effects.

6. Conclusion

This paper investigates the trade-off faced by regulators promoting market entry and static efficiency by means of regulated access and not undermining incentives to invest in infrastructure. It provides empirical evidence of this inherent trade-off between access regulation and investment incentives in network industries by differentiating between incumbents and entrants and permitting regulation to be endogenous.

We find considerable support for our approach. In particular, regulation has a quite different impact on the investment decisions of incumbents and entrants, discouraging investment by incumbents and individual entrants even as entrants' total investment increases. We find that an endogenous treatment of regulation drives these results.

These findings cast doubt on the EU regulatory environment with respect to moving toward facilities-based competition in telecommunications. Our results suggest that regulation discourages entrants' individual investment even as entry and total investment by entrants increases. Because facilities-based entry is likely to require substantial firm-level investment, our results are consistent with the view that the regulatory framework in Europe fails to deliver effective incentives to move toward facilities-based competition.

Finally, we find regulatory responses to infrastructure investments to differ between incumbents and entrants. Whereas access regulation is not affected by entrants' investment, we find that regulators respond to higher infrastructure investment by incumbents by providing easier access, thereby undermining incumbents' incentives to invest in infrastructure in the first place. This finding suggests that the regulatory environment in Europe is subject to a regulatory commitment problem.

Appendix

The Construction of the Infrastructure Variable

Table A1 contains the list of operators in our sample and details on the construction of our infrastructure variable. In general, our measure of infrastructure is domestic tangible fixed assets in the fixed-line business of each operator. In most cases, we can read this measure directly from our data ("directly measured" in Table A1). Some incumbent telecom operators, however, do not break down this measure according to the regions of operation (EU member states) and/or the function (fixed line versus mobile). To tackle these problems, we computed the infrastructure measure by (1) taking the ratio of tangible fixed assets to total assets in all markets where a given operator is active and applying this ratio to the total assets in a given member state to compute the member-state-specific tangible fixed assets ("geographic approximation" in Table A1) and/or (2) subtracting the tangible fixed assets of the mobile subsidiary from the operator's total tangible fixed assets ("functional approximation" in Table A1).

In a few cases, we were not able to perform the functional approximation and hence the infrastructure measure includes both the fixed-line and the mobile infrastructures ("no functional breakdown" in Table A1).

Table A1
Construction of Infrastructure Measure for Operators in the Sample

Country	Company	Incumbent	Infrastructure	Data Source
Austria	Telekom Austria	Yes	Geographic and functional approximation	Amadeus, Osiris
Belgium	Belgacom	Yes	Functional approximation	Amadeus, Osiris
Belgium	Colt Telecom	No	Directly measured	Amadeus
Belgium	Scarlet Telecom	No	Directly measured	Amadeus
Belgium	Tele 2	No	Directly measured	Amadeus
Belgium	Telenet	No	Directly measured	Amadeus
Belgium	Verizon	No	Directly measured	Amadeus
Belgium	Versatel	No	Directly measured	Amadeus
Bulgaria	Bulgarian Telecom	Yes	No functional breakdown	Amadeus
Denmark	TDC	Yes	Functional approximation	Amadeus
Denmark	Colt Telecom	No	Directly measured	Amadeus
Denmark	Tele2	No	Directly measured	Amadeus
Denmark	Verizon	No	Directly measured	Amadeus
Estonia	Elion Ettevõtted	Yes	Directly measured	Amadeus
Estonia	Tele2	No	Directly measured	Amadeus
France	France Telecom	Yes	Functional approximation	Amadeus, Osiris
France	BT C & SI	No	Directly measured	Amadeus
France	Colt Telecom	No	Directly measured	Amadeus
France	Intercall	No	Directly measured	Amadeus, Osiris
France	Neuf Cegetel	No	Directly measured	Amadeus, Osiris
France	Telecom Italia	No	Directly measured	Amadeus
France	Telemedia	No	Directly measured	Amadeus
France	Tiscali	No	Directly measured	Amadeus
France	Verizon	No	Directly measured	Amadeus
Germany	Deutsche Telekom	Yes	Geographic and functional approximation	Amadeus, Osiris
Germany	3U Telecom	No	Directly measured	Amadeus
Germany	Arcor	No	Directly measured	Amadeus
Germany	Freenet	No	Directly measured	Amadeus
Germany	Tiscali	No	Directly measured	Amadeus
Germany	Versatel	No	Directly measured	Amadeus
Greece	OTE Globe	Yes	Directly measured	Amadeus
Greece	Forthnet	No	Directly measured	Amadeus
Greece	Hellas On Line	No	Directly measured	Amadeus
Greece	Newsphone	No	Directly measured	Amadeus
Greece	Verizon	No	Directly measured	Amadeus
Hungary	Magyar Telekom	Yes	No functional breakdown	Amadeus
Hungary	Hungarotel	No	Directly measured	Amadeus
Hungary	Invitel	No	Directly measured	Amadeus
Hungary	UPC	No	Directly measured	Amadeus
Ireland	Eircom	Yes	No functional breakdown	Amadeus, Osiris
Ireland	BT	No	Directly measured	Amadeus

Table A1 (*Continued*)

Country	Company	Incumbent	Infrastructure	Data Source
Ireland	Colt Telecom	No	Directly measured	Amadeus
Ireland	Energis	No	Directly measured	Amadeus
Italy	Telecom Italia	Yes	Directly measured	Amadeus
Italy	Fastweb	No	Directly measured	Amadeus
Italy	Tele2	No	Directly measured	Amadeus
Italy	Tiscali	No	Directly measured	Amadeus
Italy	Wind	No	Directly measured	Amadeus
Latvia	Lattelecom	Yes	Directly measured	Amadeus
Latvia	Telekom Baltija	No	Directly measured	Amadeus
Latvia	Telekomunikaciju Grupa	No	Directly measured	Amadeus
Lithuania	Lietuvos Telekomas	Yes	No functional breakdown	Amadeus
Lithuania	TEO	No	Directly measured	Amadeus, Osiris
Malta	Maltacom	Yes	No functional breakdown	Amadeus
Poland	Telekomuni-Kacja Polska	Yes	No functional breakdown	Amadeus, Osiris
Poland	Netia	No	Directly measured	Amadeus, Osiris
Poland	Tele2	No	Directly measured	Amadeus
Portugal	PT Comunicaçoes	Yes	Directly measured	Amadeus
Portugal	Novis Telecom	No	Directly measured	Amadeus
Romania	Romtelecom	Yes	No functional breakdown	Amadeus
Romania	UPC	No	Directly measured	Amadeus
Slovenia	Telekom Slovenije	Yes	No functional breakdown	Amadeus
Sweden	Teliasonera Sverige	Yes	Directly measured	Amadeus
Sweden	Tele2	No	Directly measured	Amadeus
Sweden	Telenor	No	Directly measured	Amadeus
Sweden	Verizon	No	Directly measured	Amadeus
United Kingdom	BT	Yes	Geographic approximation	Amadeus, Osiris
United Kingdom	Adept Telecom	No	Directly measured	Amadeus, Osiris
United Kingdom	Alternative Networks	No	Directly measured	Amadeus, Osiris
United Kingdom	Colt	No	Directly measured	Amadeus
United Kingdom	Kingston	No	Directly measured	Amadeus
United Kingdom	NTL	No	Directly measured	Amadeus
United Kingdom	Pipex	No	Directly measured	Amadeus
United Kingdom	PNC Telecom	No	Directly measured	Amadeus, Osiris
United Kingdom	Telecom Plus	No	Directly measured	Amadeus
United Kingdom	THUS	No	Directly measured	Amadeus
United Kingdom	Vanco	No	Directly measured	Amadeus

Sources. Bureau van Dijk, Amadeus (http://www.bvdinfo.com/Products/Company-Information/International/Amadeus; Bureau van Dijk, Osiris (http://www.bvdinfo.com/Products/Company-Information/International/Osiris).

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