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ESMT Competition Analysis

Analysing the Relationship Between Regulation and Investment in the Telecom Sector

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I. Executive Summary

This report analyses the relationship between entry regulation and infrastructure investment in the telecommunication sector, contributing to the ongoing debate on how to reshape the regulatory framework for eCommunications. The empirical analysis is based on a comprehensive data set of investment data covering 180 fixed-line and mobile operators in 25 European countries over 10 years and employs a newly created indicator measuring regulatory intensity in the various countries.

Based on this data set, we are able to distinguish different effects of entry regulation in mobile and fixed-line segment of telecommunications, as well as on incumbents and entrants. Moreover, the dynamics of the investment process are modelled structurally in our analysis, allowing us to derive short-term and long-term effects. Furthermore, we carefully treat the endogeneity problem of regulation by identifying several instrumental variables. The instruments used in our estimations include political variables — most importantly attitude of the government toward European integration, and regulation in general — and levels of regulation in other European countries.

Based on this methodology we derive the following main results:

First, estimating a static model (that is no lagged infrastructure stock variable is included) and without controlling for the endogenity problem of regulation results in very different effects than what is found in a richer, statistically more appropriate approach. Using simplified approaches for policy advice can therefore be misleading.

Second, the dynamic specification of the model proves to be correct and robust. The magnitude of the coefficient on the lagged infrastructure variable, which is very close to 1, means that the stock of infrastructure is highly time persistent. It also suggests that shocks to economic determinants of the stock of infrastructure have very persistent effects. A 10% increase in the stock of infrastructure due to a change in some economic conditions is followed by a further 9.4% increase in infrastructure in the next year, 8.8% in two years, 8.3% in three years, and so on. The long-term effects are therefore much higher than the immediate effects according to our estimates.

Third, we find that entry regulation discourages infrastructure investment by entrants in fixed-line telecommunications. According to a simulation based on operators in our sample, introduction of regulated access to incumbents' networks costs Europe a lost investment in the amount of 25.1% of the entrants' infrastructure stock in the first year. This loss accumulates over time and reaches 111.5%, which is equivalent to €18.1 billion, over 5 years. In other words, our results suggest that the entrants would more than double their infrastructure over 5 years had they no regulated access to the incumbents' local loops. In terms of the total telecommunication investment in Europe, the lost investment is equivalent to 8.4%, which is a significant amount.

Fourth, incumbents are not found to significantly change their investment as a result of entry regulation in fixed-line telecommunications. One possible explanation of this is that entrants are

able to boost end customer demand due to increased variety and innovativeness of their information and communication services offered on incumbents' networks. In this case the lost profit margins of incumbents could be offset by the increase in total demand. It has to be highlighted that the data used for the analysis does not cover investment in next generation access networks. To the extent that the investment in next generation access networks is qualitatively different from upgrading the current infrastructure of incumbents, this result cannot be extrapolated to future investments.

Fifth, while entry regulation significantly discourages investment in fixed-lines by entrants, it seems to have no significant impact on investment in mobile telephony both by entrants and incumbents. This result may be due to the limited quality of the available indicator for entry regulation in mobile telephony, which comprises mainly the number of network-based licences. The number of network-based licences focuses — in contrast to the indicators used for fixed-line telephony — on facility-based entry, for which economic theory predicts significantly different results. Alternative indicators addressing non-facility based entry regulation, like the existence of mobile virtual network operators for instance, are not available though. Moreover, access regulation of telephony markets in Europe has started in 2003, possibly too early to be visible with the data used.

Overall, the results of this report highlight the importance of using a robust empirical approach if econometric evidence is used for policy advice. Opposite to what is derived from simplified assessments we do not find any indications that entry regulation has a positive impact on investment. On the contrary and in line with the theoretical literature, in the fixed-line sector regulators are faced with an important trade-off, where we find a significant negative effect of entry regulation on the incentives of entrants to invest. Promoting market entry by means of regulated access might have the desired short-term effect of lower prices and more consumer surplus, but at the same time undermines the incentives of entrants to invest in their own infrastructure thereby compromising on the long-term goal to establish facilities-based competition.

II. Main Discussion

1. Introduction

1.1. Background

The regulatory framework for eCommunications ("the regulatory framework") defines the fundamentals of competition for the European telecommunication sector and is currently under review by the European Commission. The issues addressed by the framework can be separated into two broad groups. First, the framework defines which market segments of the telecommunication sector should be put under an *ex ante* approach of regulation and which market segments should be left to *ex post* regulation, i.e. competition policy. This is the question of what is the optimal instrument - *ex ante* regulation or competition policy. Second, it defines and harmonises the rules for *ex ante* regulation between the European member states. This is the question of how to optimise the instrument of *ex ante* regulation.

The answer to both questions — what is the optimal policy instrument and how to optimise the instrument — is by and large determined by the trade-off between static and dynamic efficiency: low prices in the short term, enforced through access or price regulation or through effective competition, may support static efficiency but may hamper investment in infrastructure and new products in the long term, that is dynamic efficiency. A robust understanding of the trade-off between static and dynamic efficiency is therefore central to the review of the regulatory framework.

Interestingly, having more than 20 years of experience with regulating telecoms worldwide, policy makers, practitioners and scholars still do not agree on the ideal approach that would yield a right balance between static and dynamic efficiency. For instance unbundling, the leading regulatory solution both in Europe and the U.S. in the late 1990's, which consists of ensuring new entrants' access to the incumbent fixed-line infrastructure at the wholesale level, has been phased out in the U.S., while it is still dominant in Europe (Renda, 2007).

1.2. General Approach and Structure of this Study

This study intends to add to the debate on dynamic — or long-term — effects of the regulatory framework a more careful assessment of the resulting infrastructure investments in the industry. For that purpose an extensive literature review of the debate is provided and an empirical framework, which allows for robust inference given available data, is put forward.

The literature overview in the next section starts with a general assessment of the link between competition and investment and continues with a discussion of the telecom sector's specificities. We discuss the trade-offs between static and dynamic efficiency of competition when network infrastructure is difficult or impossible to duplicate and whether retail competition can lead to facilities-based competition. We also review the incentives of incumbents and entrants to invest

in infrastructure and the way mandated access at a regulated price influences these incentives. Finally, we report empirical evidence on those issues.

Section 3 reviews empirical models of telecommunication's infrastructure investment in the economic literature and proposes an econometric framework for our analysis. The most important elements of this framework are:

i) Structurally modelled dynamics of the investment process, which allow us to derive short-term and long-term effects of regulation.

ii) A careful treatment of the endogeneity problem of regulation with instrumental variables technique.

iii) Disaggregated level of analysis, which accounts for the fact that regulation is segment-specific; moreover, it allows for differential effects of regulation on the fixed-line and mobile segments, as well as on the incumbents and entrants.

This empirical framework puts relatively high requirements on data. Section 4 reviews existing data that will facilitate our empirical analysis. We concentrate on different measures of investment and regulation and highlight their advantages and disadvantages. We also provide a number of control variables for the investment analysis, as well as possible instrumental variables for the regulatory measures to address the endogeneity concerns.

Section 5 provides a non-technical discussion of our econometric results along with a simulated effect of access regulation on investment in the industry.

Section 6 concludes by summarising the debate on regulation and investment in the literature and discussing implications of our empirical results.

Finally, robustness checks, a more technical discussion of both the theoretical and the empirical model, as well as detailed description of the data used for the analysis is placed in the annex.

2. Literature Review

The ultimate reason for regulating the telecom markets is to introduce competition, which is widely believed to enhance efficiency and thereby social welfare. In the static sense, competition reduces the market power of producers, which leads to lower prices and higher surplus for customers. Competition also disciplines producers in their use of resources thereby promoting efficient use of inputs and minimising waste. To gain a more complete picture of the relationship between competition and welfare one needs, however, to extend the textbook analysis of static efficiency by dynamic considerations, in which innovation and investments are key.

2.1. The General Trade-Off in Competition on Investment

Simple models of competition suggest a negative relationship between competition and investment and innovation.[1] Models of product differentiation and monopolistic competition deliver the prediction that more competition — for instance through lower transportation cost or higher substitutability between the products — reduces post entry (or post investment) rents and thereby reduces the incentives of firms to enter a market or to invest in new products or better processes. This effect, which is called the *Schumpeterian effect* in the literature, is also the key driver of the relationship between competition and innovation in traditional models of growth.

Recent research indicates that the relationship is in fact more complex and can be characterised by an inverted U-relationship. At a relatively low pre-existing level of competition an increase in competition will foster investment and innovation. After a certain saturation point, however, further increases in competition will result in reduced investment levels. While the latter can be explained by the *Schumpeterian effect* described before, the positive effect is due to the incentive of the incumbent to *escape* competition by innovation: increased competition reduces a firm's pre-innovation rents by more than it reduces its post-innovation rents. In other words a firm can escape lower rents by innovation. Accordingly this effect is called *escape effect*.[2]

The combination of these two effects, the *Schumpeterian effect* and the *escape effect*, allows for a vast array of industry specific results, depending on the *ex ante* level of competition and the distance of the incumbent firms from the technology frontier. Complementarities between the various instruments of an effective national investment/ innovation system add complexity to this relationship.[3]

[1] Innovation can be interpreted as a specific form of investment, resulting in new or better quality products and services or in more cost efficient processes. But there are innovation specific issues, like information spillovers or the public good character of innovations which have to be taken into account. For the purpose of this overview we will abstract from those specificities and use the two notions interchangeably.

[2] See Aghion et al. (2005) and Griffith et al. (2006) for a survey of the literature. The *escape effect* is closely linked to the discussion of whether an incumbent or a potential entrant has higher incentives to innovate. See for instance Gilbert, R. and D. Newbery (1982).

[3] See Mohnen and Röller (2005) for an empirical analysis of these complementarities.

2.2. Facilities-based vs. Service-based Competition

In the context of telecommunications industries, the potential efficiency gains from competition can be severely hampered by parts of the infrastructure that have natural monopoly properties. The local loops, which connect individual households to the local switch, are the most often cited example of such infrastructure. Duplication of the copper wires constituting the local loops is prohibitively expensive, at least for the purpose of an alternative supply of traditional telecommunication service. Both in Europe and the U.S. a typical solution to this infrastructure bottleneck was the introduction of a mandated access to the incumbent telephone network by means of unbundling and sharing of the local loop.[4] The mandated access facilitates the so-called service-based competition, in which the entrant is able to compete with the incumbent in the retail market by leasing the local loop at some regulated price. This is very different from facilities-based competition, in which both the incumbent and the entrant own the essential infrastructure and no leasing arrangements are required.[5] Most of the commentators are persuaded of the advantages of the facilities-based competition in terms of variety, keen prices and innovation, whereas the service-based competition seems to provide no other benefits than keen prices through the regulator-promoted access (Cave, 2004). Empirical evidence from the broadband market in Europe indeed suggests that in particular infrastructure competition between DSL and cable TV providers had a significant positive impact on the broadband deployment (Höffler, 2007).

In the context of the present study, it is very important to distinguish between the facilities-based and the service-based competition due to their potentially very different impact on innovation and investments. In particular, pooling the fixed-line and mobile infrastructure investment might give an inaccurate picture of the response of investments to the regulator-promoted competition, as mobile telephony, in contrast to fixed-line telephony, is characterised by full-fledged facilities-based competition.

2.3. Static and Dynamic Efficiency of Access Regulation

If access regulation reduces the monopoly power over the telecommunications infrastructure, then it also reduces the rent that can be earned on an investment in this infrastructure. Access regulation based on a simple cost recovery rule, while encouraging efficient utilisation of infrastructure, risks discouraging investment (Valetti, 2003). Therefore, there seems to be a trade-off between optimal regulation in a static and in a dynamic sense.

The increased static efficiency due to access regulation seems to be undisputed.[6] There are, however, conflicting views and research results on the impact of access regulation on investments in telecommunications, although the majority of the scholars tends to agree that access regulations in fact undermines infrastructure investment. This view is also reflected in a recent shift of the Federal Communications Commission (FCC) in the U.S. away from the access regulation (Renda, 2007).

[4] See Renda (2007) for a recent overview of the industry and the regulatory trends on both sides of the Atlantic.

[5] Although leasing of infrastructure is no longer required, interconnection of the competing networks and bilateral access prices remain an issue. Regulatory concerns under this two-way network are, however, significantly reduced as compared to one-way networks, when the entrant must seek access to the incumbent's essential facilities (Valetti, 2003).

[6] Hausman and Sidak (2005) report, however, that mandatory unbundling resulting from the Telecommunications Act of 1996 does not appear to have decreased retail prices of the U.S. telecommunications services.

In the context of dynamic efficiency, there is no firm theoretical argument in favour of access regulation. In the game-theoretic models of Foros (2004) and Kotakorpi (2006), service-based competition may encourage investment by the incumbent if it brings more variety and innovative services thereby boosting end-consumers' demand. Some scholars argue along these lines to conclude that lower access prices actually increase investment in facilities (Hassett et al. 2003; Willig, 2003). It is crucial though that profit from this increased market could be appropriated by the incumbent through high enough (possibly unregulated) access charges. This explains why Wallsten (2005) finds that Unbundled Network Element (UNE) regulations are negatively correlated with broadband deployment in the U.S., but resold lines are positively correlated with it.[7] The cost-based access charges promoted by the U.S. and the European regulators have been criticised, however, for being too low (e.g. Pindyck, 2004).[8]

Nevertheless, there exists some empirical support of access regulation promoting infrastructure investment in both U.S. and Europe. After analysing the sample of 41 Incumbent Local Exchange Carriers (ILECs) over 1994-1998, Chang et al. (2003) reports that the percentage of digital lines is negatively correlated with the access price and concludes that low access prices spur incumbents' investments. Similarly, the London Economics (2006) study for Europe finds that telecoms investments are higher when regulatory regimes perform better.[9] Li and Xu (2004) also find a positive effect of competition on telecommunications investments in a study based on a panel of 177 countries. There are two main drawbacks of these studies, though: i) Correlation is often taken as evidence for causation ignoring endogeneity concerns;[10] and ii) Data for the analysis — both regulation and investment measures — is often very aggregated, which ignores specificities of the fixed-line and mobile sectors, as mentioned earlier. These drawbacks cast severe doubts on robustness of these empirical findings. To the best of our knowledge, there are no empirical studies of investment and regulation in the telecom sector that address both these drawbacks at the same time.

On the other hand, the arguments that mandated access coupled with cost-based access charges undermine innovation have a relatively strong theoretical underpinning and include: i) Lowering the option value of the incumbent's investment, ii) Shifting the burden of risk from the entrant to the incumbent and iii) Increasing the incumbent's cost of capital. The first argument raised by many scholars (e.g. Haring and Rohlfs, 2002; Pindyck, 2004) says that by limiting future streams of profits on an investment access regulation decreases the Net Present Value (NPV) of the investment and thereby makes it less attractive for the investor.[11] In fact, this intuition drives the result that a lower unbundling price reduces the incumbent's and entrant's infrastructure investment in many formal models (e.g. Foros, 2004; Zarakas et al. 2005; Kotakorpi, 2006; Vareda, 2007).

The second argument points to the fact that the telecommunications infrastructure investment is highly uncertain and that the cost-based access charges do not take full account of that (e.g.

[7] UNE regulated prices were supposed to reflect the cost an incumbent would incur to provide each network element, while resale prices were supposed to be a discount from retail prices reflecting the incumbent's avoided costs of providing certain customer services. Hence, it was generally less expensive for competitors to provide service through UNE lines.

[8] See Valetti (2003) and Vogelsang (2003) for a general overview of the access pricing and its possible effect on innovation and investment.

[9] The performance of the regulatory regimes is measured by the OECD regulatory index, which is composed of three sub-indices: i) legal barriers of entry, ii) level of public ownership in telecoms and iii) market shares of entrants.

[10] This issue is addressed in more detail in the section on determinants of regulatory outcomes.

[11] See Pindyck (2004) for an introduction to the concept of option value and its application to investments in telecommunications infrastructure.

Jorde et al., 2000; Haring and Rohlfs, 2002; Valetti, 2003; Pindyck, 2004; Baake et al., 2005). Instead, the mandated access charges give a risk-free option for entrants to lease the infrastructure and exploit the regulatory arbitrage between wholesale and retail prices. This in fact adversely affects the *ex ante* incentives of entrants to invest in their own infrastructure.

Besides, by shifting the burden of risk from the entrant to the incumbent, the cost-base access regulation may also increase the incumbent's cost of capital (Jorde et al., 2000) by diminishing its ability to invest. In particular, entrants are more likely to lease the local loops in case of unfavourable realisation of the uncertainty, i.e. when demand for telecommunications services turns out to be weak. Alternatively, when the demand is strong, higher prices for the services will afford entrants to roll out their own networks. Because the cost-base access charges undercompensate the incumbent, its returns will suffer in times of recession and improve during an expansion. This increased volatility of incumbent's returns on assets relative to the market has to be compensated by higher returns on its stocks for the investors, which increase incumbent's cost of equity. In their econometric analysis based on U.S. data Ingraham and Sidak (2003) found empirical support for this hypothesis.

There also exists some more general empirical evidence of the discouraging impact of access regulation on the investments in telecommunications. After analysing the industry trends in the U.S., the U.K., New Zealand, Canada and Germany, Hausman and Sidak (2005) concluded that mandatory unbundling did not spur infrastructure investments neither by incumbents nor by entrants. Using data from the U.S. over the period 2000-2001, Crandall et al. (2004) estimated that the share of the entrants' lines that are facilities-based is lower in the U.S. where the local loop rental rates are lower. Applying similar methods with European data, Waverman et al. (2007) demonstrated a strong substitution from broadband offered over alternative access platforms toward unbundled-loop-based offerings when local loop prices were low. This suggests that unbundling decreases entrant's investment in infrastructure and as a consequence facilities-based competition is lessened. In the same way, Eisner and Lehman (2001) found that states with lower unbundling rates experienced less facilities-based entry. Other studies found also a detrimental effect of unbundling policies on incumbent's investments (Haring, Rettle, et al. 2002; Crandall and Singer, 2003). Finally, Wallsten (2006) estimated the impact of local loop unbundling on broadband deployment to be insignificant or even negative in the OECD countries. These econometric studies ignore, however, the endogeneity of regulatory policies, which may significantly bias the results.

2.4. Can Service-based Competition Lead to Facilities-based Competition?

Proponents of the access regulation stress that although low access fees may not promote infrastructure investments, they do allow the entrants to climb the first rung of an investment ladder (Cave and Vogelsang, 2003; Cave 2004). In the first step an entrant would be able to attract its installed base of subscribers and gain a better understanding of the demand and the costs by leasing the parts of the incumbent's infrastructure that are very costly to duplicate. After accomplishing this first step, an increase in access charges together with technological progress and falling costs should encourage the entrant to roll out its own network and start the facilities-based competition. This logic is consistent with the formal model of Bourreau and Dogan (2005), who show that the optimal access charge from incumbent's viewpoint would be prohibitively high during the time when there is no effective threat of facilities-based entry due to high investments costs. This access charge would then decrease over time together with

technological progress, which renders the entry less expensive. By following this strategy, the incumbent could delay the facilities-based entry and at the same time extract maximum rent from the entrant.

The “ladder of investment” approach has been, however, heavily criticised by some scholars for not being effective in practice. After analysing industry trends, Hausman and Sidak (2005) found no evidence in favour of the “ladder of investment” hypothesis in the U.S., the U.K., New Zealand, Canada, and Germany. Hazlett and Bazelon (2005) reached the same conclusion based again on the U.S. data. We are not aware, however, of any systematic econometric study that would support or reject this hypothesis.

3. An Empirical Framework

In this section we review the empirical models of infrastructure investment and regulation that have been used in the literature. In particular, we highlight the theoretical underpinning, as well as the treatment of the endogeneity problem in these models, as this is fundamental for the proper interpretation of the results. Next, we present our preferred model to be used in the subsequent analysis.

3.1. Existing Empirical Models of Infrastructure Investments

Most of the existing empirical models on infrastructure investments take explicitly or implicitly a reduced-form approach, in which investments or infrastructure level depends on a set of supply and demand characteristics (e.g. Chang et al., 2003; Crandall et al., 2004; Henisz and Zelner, 2001; Höffler, 2007; Wallsten, 2003). The only exception that we are aware of is the model of Röller and Waverman (2001), who estimate both the supply of and the demand for telecommunications infrastructure. One advantage of their structural approach is that it allows a predicting impact of the variable of interest separately on the demand and the supply. This might be important for instance if one wants to test the specific hypothesis — introduced in the literature review section — that access regulation boosts the end-consumer demand for infrastructure via innovative services of the retail competitors. This boost of demand may in turn induce more infrastructure investments by the incumbent.[12] In contrast, the reduced-form model would be able to deliver only an estimate of the aggregated effect of demand and supply on the equilibrium level of infrastructure.

Another dimension that differentiates the empirical models is the use of dynamics. Static models assume that all relationships in the model occur immediately in a given period of time. One could, however, easily imagine that some effects might be postponed in time or occur with a different strength in the short and in the long run. The most simple way to account for these dynamics is to introduce lagged explanatory and lagged dependent variables to the model (e.g. Alesina et al., 2005). Greenstein et al. (1995) put more structure into the hypothesised dynamic process by considering a long-term equilibrium relation along with an adjustment equation. By doing so they derived an infrastructure equation with structural lags. For an investment model it is very important to incorporate these dynamics. Some of the investment decisions can be taken immediately and will add to the observable short term effects. Some of these decisions need adjustment time and will therefore only gradually translate into real effects. Hence, the accumulated effect can significantly differ from the short term effect. A static model, which basically captures the short term effects, can significantly misrepresent the true relationship.

Endogeneity issues also proved important in the models with regulatory variables. There are two main sources of endogeneity: reverse causality and omitted variables. Crandall (2005, p.71) points out the reverse causality problem by showing that the U.S. access prices in 2002 are negatively correlated with 1996-99 capital spendings of incumbent telecoms companies. Running

[12] This boost of demand should not be mistaken with moving along the demand curve by forcing the prices to fall. It should rather be understood as an outward shift of the demand curve.

a regression of capital spending on access prices, it is then very likely to find that lower prices are correlated with higher capital spendings, which may have nothing to do with the true causal effect of regulation on investments.

Omitted variables might also lead to endogeneity and hence biased estimates. Considering for instance a hypothetical world, in which regulation has no effect on investment, but facilities-based competition has a significant positive effect. Being aware of these competition effects but ignorant about own powerlessness, the regulators might choose a "hand-off" approach when the facilities-based competition is strong. An empirical analysis of the effect of regulation on investment ignoring the competition would then find a negative effect of regulation on investment, when in fact there is no such effect. A careful choice of variables and panel data techniques help to mitigate the omitted variable problem. More generally, the endogeneity issues can also be tackled with the instrumental variables (IV) techniques.

Most of the above-cited studies acknowledge the potential endogeneity of regulation without controlling it. Studies that address the endogeneity problem by using IV-techniques include Gual and Trillas (2004), Gutierrez (2003) and Li and Xu (2004). Small sample size and high aggregation of the data, however, undermine robustness of the results in these studies.

3.2. Determinants of Regulatory Outcomes

All regulatory outcomes including unbundling policies and mandated access prices are the effect of political and administrative processes, which can interact with the investment decisions by firms. This is crucial for the econometric modelling of the investments and known in the econometric literature as endogeneity problem. Ignoring the endogeneity might lead to severe biases in the empirical results and difficulties for interpretation of the results, as highlighted in the previous section. In order to account for the endogeneity it is important to know what the determinants of regulatory outcomes are.[13]

While the relevance of this argument was pointed out already by Stigler (1971), only recently empirical studies established a close link between political and institutional factors and the design and the effectiveness of regulation. For instance, Neven and Röller (2000), Duso and Röller (2003) and Duso (2005) show that political and institutional factors explain a substantial part of the variation in subsidy levels between various EU countries, the degree of deregulation achieved in various OECD countries in the mobile telecommunication industry and price regulation in the U.S. mobile industry, respectively. These political and institutional factors include governments' general ideologies (left vs. right wing), governments' attitudes toward market regulations, electoral systems, political systems (presidential vs. parliamentary), accountabilities and independence of the regulatory agencies, as well as electoral campaigns' contributions. While the list of scholars, who seek to explain the regulatory policies, is much longer than the one cited here, the list of explanatory variables used typically includes the above variables.

As also shown in the above cited studies, one additional factor which explains the regulatory policies is the performance of the regulated market itself. In fact, this is one potential source of

[13] If we find the regulatory determinants that are not correlated with the dependent variable — infrastructure investment in this study — we can use them as instrumental variables.

endogeneity in models that empirically estimate the relationship between the performance — measured for instance by investments — and the regulatory measures. If the causality does not only go from regulation to performance, but also in the reverse direction, then the simple correlation between these two variables will reflect an average between these two causal relationships. For instance Crandall (2005, p.71) shows that the U.S. access prices in 2002 were negatively correlated with 1996-99 capital spending of incumbent telecoms companies, which suggests that regulators exploit investment *ex post* by reducing the rate at which the investing company is obliged to lease its network to competitors.

3.3. Determinants of Infrastructure Investments

Based on the literature reviewed in previous sections we identify four groups of variables that are likely to affect the infrastructure investment of a firm: i) demand shifters, ii) cost shifters, iii) competitive pressure and iv) regulation. The first group consists of variables affecting consumer demand for telecommunications infrastructure. These variables include consumer wealth typically measured by GDP per capita.

The second group covers investment cost shifters. Because the density of households determines to a large extent the costs of building the local loops, a natural cost measure is the population density and the level of urbanisation. The costs of labour and capital obviously play an important role as well. The cost of labour in the construction sector seems particularly relevant for the infrastructure investment and the debt level of a firm may serve as a good proxy of its cost of capital. Many commentators also point to the dot.com bubble, which burst in 2001, severely affecting the investments that the telecoms operators could afford. The stock market bubble can be accounted for by means of time period (year) dummy variables.

The third group of variables comprises measures of competitive pressure.[14] In particular, investment incentives of telecom companies can be influenced by facilities-based competition from alternative platforms. One such measure used in the literature is cable TV penetration, as cable broadband offerings directly compete with DSL broadband access over fixed-lines. By the same token, the number of main lines in a country constitutes a measure of competitive pressure in mobile telecoms.[15]

Regulatory policies constitute the forth group of relevant variables. Among them entry regulation including unbundling and sharing of the local loop are most heavily disputed.

Finally, but most importantly, we have identified a set of instrumental variables in order to control the endogeneity of regulatory policies. The following variables have been identified as potential instruments in our estimations:

[14] A sustainable competition is an ultimate goal of the telecom sector's regulation in Europe, but the two should not be confused.

[15] It is important to stress here that the optimal choice of explanatory variables should not aim to explain as much variation in the investment variable as possible, but rather minimise omitted variable problems thereby contributing to the accuracy of estimates on the regulatory variables. Inclusion of variables that might be correlated with investment levels as well as regulatory policies (like the installed cable TV infrastructure) is then crucial.

- **Political variables:** Political ideology of the government, attitude of the government toward European integration, attitude of the government toward regulation, as well as the level of checks and balances constraining the discretion of politicians' and bureaucrats' decisions.

- **Neighbouring markets:** We also consider using the level of regulation in other European countries as possible instrument.

3.4. The Econometric Model

The econometric model that we propose follows Greenstein et al. (1995). It is a partial adjustment model, in which the current infrastructure stock is a weighted average of the long-run desired stock and of the lagged stock value, where the weights reflect the speed of adjustment to long-run equilibrium.

As shown in the annex, the partial adjustment model yields the following estimation equation:

$$Infr_{kjt} = a_0 + a_1 Infr_{kjt-1} + Demand_{kjt}\beta_1 + Cost_{kjt}\beta_2 + Comp_{kjt}\beta_3 + Reg_{kjt}\beta_4 + v_{kjt}. \quad (1)$$

$Infr_{kjt}$ reflects the stock of infrastructure for firm j in country k in time period t and $Infr_{kjt-1}$ is the stock of infrastructure in the previous period. $Demand_{kjt}$, $Cost_{kjt}$, $Comp_{kjt}$ and Reg_{kjt} stand for the four groups of variables that determine the infrastructure investment, as identified in the previous section, and β_1 through β_4 denote the respective four groups of coefficients for these variables. Finally, v_{kjt} is a usual error term, which captures the variation in the infrastructure that is not explained by the model.

The lagged dependent variable $Infr_{kjt-1}$ in equation (1) distinguishes this model from standard static linear regression models. The inclusion of the lagged dependent variable follows from the assumption that firms do not immediately adjust the level of infrastructure to changing market conditions. Instead, the adjustment is distributed over years and in each year only a fraction of an optimal long-term investment is actually undertaken. The investment process is then assumed to exhibit certain inertia, which is reflected by the coefficient a_1.

The estimation of eq. (1) provides then information on two aspects of the investment process: First, the estimates of β_1 through β_4 provide the short-run effects of regulatory and economic variables on the stock of infrastructure; second, a_1 reflects the speed of adjustment and, as a consequence, the long-run effects on infrastructure.

4. Data

This section presents the data we use in the analysis. First, we discuss in some detail the main variables of the study, i.e. the investment and the regulatory variables. Second, we present the set of explanatory variables and the variables that we use as instruments to address the endogeneity of regulation.

4.1. Investment and Regulation Measures

In our search for the investment variable that would facilitate our empirical analysis we followed three main criteria: i) proximity to the real infrastructure or infrastructure investment, ii) extensive coverage in terms of European countries and time periods, iii) sufficient level of disaggregation in terms of geographical markets and service segments (fixed-line vs. mobile).

The stock of infrastructure and the level of infrastructure investment can be measured in many ways. One variable often used in the literature is the physical amount of infrastructure measured in the number of main telephone lines, kilometres of fibre optic cables, share of digital lines, etc. The number of main telephone lines is a readily available variable for European markets, but the more detailed measures are not.

We therefore concentrate on financial measures of infrastructure stock investments, which include tangible fixed assets, Property, Plant & Equipment (PPE), additions to (tangible) fixed assets, additions to PPE, capital expenditures (CAPEX), and country-level aggregated investments in telecoms. These variables differ in terms of the proximity to real infrastructure investments, as well as their availability, sample coverage and the level of aggregation, which creates trade-offs. In short, one could either choose a more precise variable or a variable with larger sample coverage. For instance, firm-level CAPEX from the Osiris database is a very accurate measure of infrastructure investment and is disaggregated to the country level, but only some 60 data points are available. The ITU database in turn offers country-level investment figures separately for fixed-line and mobile telecoms, but only 180 data points are available over the period 1990-2006. Moreover, ITU figures do not distinguish between the incumbents' and the entrants' investments. On the other hand, there are over 1.000 observations for tangible fixed assets available from Amadeus database (supplemented with some figures from Osiris). These tangible fixed asset figures are geographically well-defined (country-level) and come from more than 200 firms (incumbents and entrants; fixed-line and mobile sector) in more than 30 European countries over the period 1997-2006, which offers a very rich variation both across countries and in time. The disadvantage of tangible fixed assets as a basis for investment measures is that they are affected by revaluations, as well as mergers and acquisitions (M&A), which do not count towards real infrastructure investments. This will not be a problem for an econometric model if the M&A and the revaluations are not correlated with the explanatory variables of the model. They will then merely enter the error term v_{kjt}. To the extent that there are some spillover effects between merger control and regulatory policy in a country, however, there will be an

endogeneity bias in the estimated coefficients on the regulatory variables. This problem can be addressed by including a variable reflecting M&A activity of the firm.[16]

The current infrastructure stock $Infr_{kjt}$ in equation (1) is then measured by a firm's tangible fixed assets deflated by the Producer Price Index (PPI) for telecom equipment. This measure fits well with the econometric framework of our analysis and allows us to gain detailed insights into the investment process in the industry. It was taken great care to assure that our infrastructure measure corresponds well to the geographic markets, which are defined by countries' borders, as well as to the market segments (mobile vs. fixed-line). The list of companies in our sample together with a detailed description of how the infrastructure measure was constructed is reported in the annex.

The regulation variables that we use in our analysis come from Plaut Economics (Zehnhäusern et al., 2007). The advantage of Plaut's regulatory index is its detailed information on different regulatory measures in the telecom sector and the comprehensive coverage in terms of countries and years. It is available for all 27 EU countries over the period 1997-2006. The index is divided into sub-indices, for price regulation, quantity regulation, market entry regulation and for miscellaneous other regulations. Price regulation scores the interconnection-regime and existence of sector-specific retail price-regulation with regards to fixed and mobile telecom, as well as potential F2M-termination regulation. Quantity regulation scores the existence of a Universal Service Obligation burden for incumbents or other telecom companies by the NRA and the existence of meet-demand-clauses for specific products or services at regulated (retail) prices or regulatory requirements regarding the coverage of mobile telephony-services. Market entry regulation scores the existence of regulated vertical separation or an accounting separation obligation, existence of various types of regulated access to the incumbent's network and the number of network-based 2G/3G mobile licenses. Finally, miscellaneous regulation scores the percentage of government-ownership of the incumbent, existence of a "golden share", access regulation asymmetry between DSL and cable network providers, existence of a sector-specific regulation in favour of protecting the environment, etc.

In line with the current political and scholarly debates, we focus on market entry regulation among all regulatory tools used in the telecom sector. The modular construction of the Plaut's regulatory index allows us to construct segment-specific indices for the mobile and fixed-line segments. Our regulatory index for the fixed-line segment is an average of indicators referring to the existence of regulated vertical separation and an accounting separation obligation, as well as the existence of regulation regarding the full unbundling, line sharing, bitstream access and subloop unbundling of the fixed-line incumbent's local loop.[17]

For the mobile segment, our regulatory index is an average of indicators referring to the number of network-based 2G and 3G mobile licenses and the constraints on the trade of frequencies.[18] Besides the lower number of sub-indices available, the indicators for mobile telephony have to be treated with some caution for the purpose of this study. The number of network-based licences focuses – in contrast to the indicators used for fixed-line telephony - on facility-based

[16] Since political and institutional variables may affect the merger control as well as the regulation, the IV estimator based on these instruments, which we apply as a general remedy to endogeneity, may not be immune to this particular endogeneity problem.

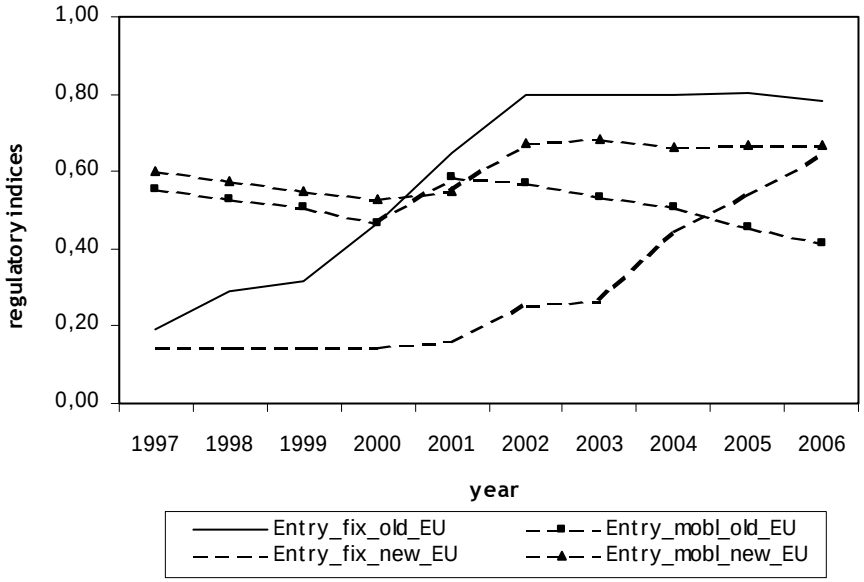
[17] The indicators entering our regulatory index for the fixed-line segment correspond to the keys 11 through 16 and 22 of the Plaut's index.

[18] The indicators entering our regulatory index for the mobile segment correspond to the keys 17 through 19 of the Plaut's index.

entry, for which economic theory predicts significantly different results. But alternative indicators addressing non-facility based entry regulation, like the existence of mobile virtual network operators for instance, are not available. The interpretation of the results has to take this into account when comparing the outcome for fixed-line telephony and mobile telephony.[19]

Figure 1 shows the evolution of the European telecom sector's entry regulation, as defined in our analysis, over the last 10 years. The "old" EU members (EU 15) experienced growing regulatory intensity in the fixed-line segment, which levelled-off in 2002. The new member states, in contrast, did not introduce any substantial measure promoting entrants to the fixed-line telephony until the eve of the 2004 EU accession.

Figure 1: Entry Regulation in Fixed-line vs. Mobile Telephony in EU Markets



Source: Authors' calculations based on data from Plaut Economics

The regulation of mobile telephony, mainly driven by licensing, was much more stable over time and equal across the new and the old member states. The fall in the index for the old Europe starting in 2001 can be attributed to the new 3G mobile licenses being granted as the new technology made its inroad to the markets.[20]

To sum up, the main variables of our study — stock of infrastructure and entry regulation in the mobile sector — are sufficiently disaggregated to pinpoint the differential impact of regulation on investments across the industry's segments, as suggested by the theoretical literature. Having such a rich firm-level data will also allow us to study the asymmetries between incumbents and

[19] A further limitation of the number of licenses granted as an indicator for entry regulation is that it does not include information on coverage obligations linked to those licenses. The impact of licenses which oblige the licensee to a specific level of investment will have a significantly different effect on investment levels than licensees granted without such a coverage obligation.

[20] More licenses are attributed to less regulation (more competition) by the index.

entrants. Finally, the large coverage of our sample in terms of geographical markets and years facilitates a robust econometric analysis.

4.2. Other Control and Instrumental Variables

The definitions and sources of all variables used in the estimation of equation (1) are reported in Table 1.

Table 2 reports the descriptive statistics. The first group of explanatory variables, referred to as main controls in the tables, includes demand shifter (GDPpc) along with an array of variables controlling for different types of companies in our sample. In particular, we distinguish between mobile operators from fixed-line operators and incumbents from entrants among fixed-line operators.[21] Because we could not obtain data for domestic fixed-line infrastructure for 10 out of 25 fixed-line incumbents in our sample, the infrastructure measure includes other operations of these companies as well, most importantly their mobile telephone operations. The Multisec indicator variable accounts for this.

Given the measure of infrastructure that we apply, it is important to control for M&A activities of the companies, as mentioned in the previous section. M&A transaction data was obtained from the SDC Platinum M&A database. Updated daily, the database offers detailed information on merger transactions including acquirer and target profiles, deal terms, financial and legal advisor assignments, deal value and deal status. This database includes alliances with a deal value of more than one million USD, thus ensuring that the overwhelming majority of mergers are covered. Mergers which took place in the telecommunications services industry in the EU region were selected and matched to our firm-level data set. Hereby, care has been taken to identify geographical ties of the transactions performed by multinational companies. Our final sample of merger transactions contains information on 229 completed deals announced during the period from 1997 to 2006 which were carried out by 54 firms. The values of the merger transactions were determined, while for multiple transactions by the same company in a given year, the sum of deal values has been computed correspondingly.

[21] We ignore the distinction between incumbents and entrants in the mobile telephony, because the asymmetries between them are far less important in practice. In particular, mobile entrants are not granted one-way access to the incumbents' network.

Table 1: Definition of Variables

Variable	Definition	Source
Dependent variable:		
Infr	Tangible fixed assets in domestic sub-sector (mio €, 2000 prices)	Amadeus Osiris
Main controls		
Mobile	Dummy = 1 if company is a mobile phone operator	Amadeus Osiris
Incumb	Dummy = 1 if company is an incumbent PTE (fixed-line)	Amadeus Osiris
Entrant	Dummy = 1 if company is a fixed-line entrant	Amadeus Osiris
Multisec	Dummy = 1 if assets of incumbent PTE include those employed in other than fixed-line operations (most importantly – mobile telecommunications)	Amadeus Osiris
M&A	Value of M&A transactions (mio €, 2000 prices)	SDC Platinum M&A
GDPpc	Gross domestic product per capita (€, 2000 prices)	World Bank's WDI
Regulation:		
EntryFix	Index of entry regulation in fixed-line markets	Plaut Economics
EntryMob	Index of entry regulation in fixed-line markets	Plaut Economics
Cost shifters:		
Labour	Annual index of labour input cost in construction	Eurostat
Debt	Ratio of long-term debt to total assets	Amadeus Osiris
PopDens	Pop dens Population density (people per sq. km)	World Bank's WDI
Competition:		
CompFix	Penetration rate of cable TV (households passed by cable)	OECD Communication Outlook
CompMob	Main telephone lines (fixed-lines) per 100 inhabitants	ITU World Telecom/ICT Indicators
Instruments:		
EntryFixNeighbour	Index of entry regulation in neighbouring fixed-line markets defined as average regulation in corresponding European countries	Plaut Economics
EntryMobNeighbour	Index of entry regulation in neighbouring mobile markets defined as average regulation in corresponding European countries	Plaut Economics
Regul	Measure of government's attitude toward market regulation	Manifesto Project
Rile	Right-left position of government	Manifesto Project
Europ	Measure of government's attitude towards European integration	Manifesto Project

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent variable:					
Infr (mio €, 2000 prices)	1083	762.27	1,913.70	.0037	22,896.69
only Mobile	457	824.74	1,375.40	.0222	10,771.44
only Incumb	141	2,483.77	4,118.25	.0545	22,896.69
only Entrant	485	202.95	564.40	.0037	5,985.37
Main controls:					
Mobile	1083	.42	.49	0	1
Incumb	1083	.14	.35	0	1
Entrant	1083	.44	.49	0	1
Multisec	1083	.07	.26	0	1
M&A (mio €, 2000 prices)	1083	194.73	2,177.04	0	44,883.18
GDPpc (€, 2000 prices)	1083	16,016.05	8,950.33	1,450.22	43,357.70
Regulation:					
EntryFix	1083	.5458	.2837	.1428	.8571
EntryMob	1083	.5458	.1622	.1666	.8666
Cost shifters:					
Labour	1071	106.3	9.7	65.5	168.4
Debt	959	.22	.51	0	5.09
PopDens	1083	34.79	27.46	10.31	99.32
Competition:					
CompFix	702	52.52	28.35	0	100
CompMob	1027	.4673	.1331	.1505	.7576
Instruments:					
EntryFixNeighbour	1083	.5168	.2497	.1428	.7802
EntryMobNeighbour	1083	.5100	.0705	.4230	.7333
Regul	935	1.64	1.01	0	4.47
Rile	935	1.72	8.23	-12.64	28.47
Europ	935	2.68	1.73	-.78	7.18

The other control variables used in our analysis include various cost shifters and competition measures. Population density and labour costs in construction reflect the costs of infrastructure deployment. Furthermore, the debt ratio of a company may affect the financial conditions under which the infrastructure investment is financed. In short, the cost of capital may increase with the debt ratio leading to less investment. Finally, our competition measures are defined as penetration rate of cable TV and main telephone lines per capita for the fixed-line and mobile telephony, respectively.[22]

Table 1 and Table 2 report also the instrumental variables that we used to account for endogeneity of the regulation. First, we construct two geographical variables, EntryFixNeighbour and EntryMobNeighbour, capturing the average level of entry regulation in neighbouring markets. Moreover, in defining the neighbouring markets we distinguish between the "old" EU (EU 15) and

[22] Missing values in the time series for penetration rate of cable TV were filled by linear interpolation; 25% out of the 702 observations in the cable TV series were constructed this way.

the "new" EU members, because the regulation of telecom sectors crucially depends on the EU accession, as illustrated in Figure 1. The neighbouring markets for Germany and Poland for instance are all other old EU members and all other new EU members, respectively.

Besides the geographical instruments, we also utilise variables measuring political environment in the European countries. The variables come from the Manifesto Project, which deals with different aspects of structures and performances of parliamentary democracies. The project focuses on quantitative content analyses of party manifestos from 50 countries covering all free democratic elections since 1945 to measure political positions of all relevant parliamentary parties.[23] The variables that we extract from this rich database are the overall policy positions of the government in terms of right versus left scale (Rile) and favouring market regulation (Regul), as well as the government's attitude towards European integration (Europ). The position of government is defined as the weighted average score of parties in the government and the weights are constructed as the proportion of parliamentary seats held by each party. In the election years, the government position is taken as the average position of the two consecutive governments weighted by the number of months in the office.

[23] See Klingeman et al. (2006)

5. Empirical Results

This section contains a non-technical discussion of our results including a simulated impact of entry regulation on investment. A more technical discussion of the results, statistical properties of the estimated model and various robustness checks that we performed are presented in the annex.

Table 3 shows the estimation results of the preferred specification of our econometric model. The continuous variables in the model are in logarithms, which allows us to interpret the respective coefficients as elasticities. The list of explanatory variables excludes the cost shifters and competition measures, as they turned out insignificant in the regressions. The results in Table 3 are, however, robust to inclusion of these additional controls, as demonstrated in the annex. Country and year dummy variables are also included in the estimation, but are not shown in Table 3 for brevity's sake. Country dummy variables capture all country-specific determinants of firms' investments, like consumer tastes, institutional environments, geographic characteristics, etc. to the extent that these do not change over time. The coefficients on the country dummy variables reflect then all these possible effects and are very useful as controls for possible omitted variables in the regression. Similarly, year dummy variables capture macroeconomic shocks that affect all firms in the analysis. For instance, the stock market bubble, which affected the investments that the telecom operators could afford, can be accounted for by year dummy variables.

The results in Table 3 are obtained by Instrumental Variables (IV) estimation and show very high statistical significance. Very good statistical properties of the model and its robustness to alternative specifications are further documented in the annex. The dynamic specification of the model proved to be correct, as the coefficient on the lagged dependent variable is highly significant. The magnitude of the coefficient, which is very close to 1, means that the stock of infrastructure is highly time persistent. It also suggests that shocks to economic determinants of the stock of infrastructure have very persistent effects. A 10% increase in the stock of infrastructure due to a change in some economic conditions is followed by a further 9.4% increase in infrastructure in the next year, 8.8% in two years, 8.3% in three years and so on. The long-term effects are therefore much higher than the immediate effects according to our estimates.[24]

[24] Because the coefficient on lagged dependent variable is almost 1, we can actually redefine our dependent variable as log(Infr/Infr(-1)), i.e. the index of infrastructure, and interpret our results as infrastructure investment elasticities rather than infrastructure stock elasticities. The accuracy of this interpretation is higher when the time horizon is shorter.

Table 3: Dynamic Model of Investment: Instrumental Variables (IV) Estimation Results

Dependent variable: **Log(Infr)**

	(1)
Log(Infr) (-1)	0.94***
	(0.02)
Mobile	-0.63
	(0.49)
Incumb	-0.41***
	(0.08)
Multisec	0.27**
	(0.12)
Log(M&A) * I(M&A>0)	0.04**
	(0.02)
Log(GDPpc)	0.52**
	(0.26)
EntryFix[1] * Incumb	-0.02
	(0.21)
EntryFix[1] * Entrant	-0.44***
	(0.15)
EntryMob[1] * Mobile	0.87
	(0.82)
Observations	730
R-squared	0.96

Notes:
Robust standard errors are in parentheses.
The estimates for intercept, country-specific effects and year dummies are not shown.
* Significant at 10%; ** significant at 5%; *** significant at 1%.
[1] Endogenous variables: EntryFix and EntryMob; Instrumental variables: EntryFixNeighbour, EntryMobNeighbour, Regul, Rile, Europ and interactions thereof.

Our estimates for Mobile and Incumbent dummy variables further suggest that there is no significant difference in infrastructure investments between mobile phone operators and entrants into the fixed-line segment; however, relative to their infrastructure stock, the fixed-line incumbents' investments are on average 41% lower than the investments of entrants. This result is very intuitive, as the infrastructure stock of an average entrant in our sample is more than 10 times smaller (see Table 2) implying that the relative dynamics are likely to be higher.

The controls for incumbents operating in multiple segments (Multisec) and M&A activities also turned out to be significant. The positive coefficient for Multisec is likely to be driven by the fact that the mobile telephone infrastructure shows higher dynamics than the fixed-line incumbents' infrastructure, as suggested by the estimates for Mobile and Incumbent dummy variables. The other interpretation is that the incumbents in the new member states, for which the segment break down of infrastructure figures is typically not available, are "catching up" with the old

member states' standards. By checking the operators' M&A activities we include only the observations with non-zero values, which is why the indicator variable I(M&A>0) is interacted with the M&A variable in Table 3. The coefficient on this interaction variable is positive, as expected, but very low. This might reflect the fact that M&A deal values are largely driven by other than tangible assets.

The demand shifter measured by GDP per capita is also positive and significant in the regression, as expected. The estimated elasticity of 0.52 means that a 10% increase in average income per capita increases infrastructure investment by roughly 5%. Other control variables — cost shifters and competition measures — turned out insignificant in our regressions. One explanation for this is that we already control a large fraction of cost and competition differences between countries by means of country-specific effects. Therefore our additional explanatory variables do not seem to be precise enough to further explain the firm-level investment decisions.

Finally, turning to the regulatory variables — the focus of this study — we see a big asymmetry between segments as well as incumbents and entrants. Entry regulation seems to have no significant impact on investment in mobile telephony, but it significantly discourages investment in fixed-lines.

For the mobile segment, it has to be recalled that our regulatory index is an average of indicators referring to the number of network-based 2G and 3G mobile licenses and the constraints on the trade of frequencies. As pointed out before, the number of network-based licences focuses – in contrast to the indicators used for fixed-line telephony - on facility-based entry, for which economic theory predicts significantly different results. This has to be taken into account when comparing the outcome for fixed-line telephony and mobile telephony. A more consistent comparison of the estimation results for fixed-line telephony and mobile telephony would require an indicator focusing on serviced-based entry regulation in the mobile telephony sector. The existence of mobile virtual network operators on investment could be such an indicator, but is not available in the indicator set employed throughout this study.

In the fixed-line segment, entry regulation has a significant negative effect on the infrastructure investment by entrants. This result is consistent with theoretical predictions and existing empirical studies on regulation and investment in the telecom sector. In particular, it corroborates the finding in Waverman et al. (2007) that the intensity of access regulation in Europe negatively affects investment in alternative and new access infrastructure. It is important to stress that Waverman et al. (2007) arrive at the same result as we do using a very different empirical approach. First, they measure access regulation as LLU prices rather than an indicator of existence of various types of access regulation and vertical separation of the incumbent operator. Second, they measure entrants' investment as the number of new broadband subscribers over alternatives like the LLU-based access platforms rather than a change in tangible fixed assets. Third, they utilise data aggregated to the country level rather than individual operators' data.

According to our estimate, an increase in the regulation index from 0 to 1 leads to a decrease in investment by 44%. To gain a better understanding of what this number means, we suppose that the NRA introduce an additional mode of regulated access to the incumbent's local loop; it could be for instance full unbundling, line sharing, or bitstream access. One such additional mode of

access increases our regulation index by 0.14, leading to a decrease in investment by more than 6% on average.[25]

Another exercise we perform in order to quantify this effect is to simulate the aggregated loss in investment due to access regulation. The assumptions of the simulation are as follows:

- Countries: 25 EU members in our sample
- Time horizon: 5 years
- Access regulation: aggregated effect of all 4 means of access to incumbent's local loop (full unbundling, line sharing, bitstream access, subloop unbundling)

Our estimates suggest that the immediate effect of introduction of this access regulation — which corresponds to an increase in the regulatory index by 0.57 — is a lost investment in the amount of 25.1% of the entrants' infrastructure stock. In the following year the lost investments amounts to 23.6%, in two years – 22.2%, in three years – 20.9%, and in four years – 19.6%. The cumulative loss in investment over 5 years is then 111.5% of the entrants' infrastructure stock. In other words, our results suggest that the entrants would more than double their infrastructure over 5 years if they did not have regulated access to the incumbents' local loops. Accounting only for the companies in our sample — 80 entrants with an average infrastructure stock of €202.95 million — this loss amounts to € 4.1 billion in the first year and €18.1 billion over 5 years, which is equivalent to some 8.4% of the total telecommunication investment in Europe.[26]

In contrast to the entrants, the incumbents are not found to significantly decrease their investment as a result of entry regulation. One possible explanation of this finding is that entrants are able to boost end customer demand due to increased variety and innovativeness of their information and communication services offered on incumbents' networks. In this case the lost profit margins of incumbents could be offset by the increase in total demand. It has to be highlighted though that the data used for the analysis does not cover investment in next generation access networks. To the extent that the investment in next generation networks is qualitatively different from upgrading the current infrastructure of incumbents, this result cannot be extrapolated to future investments.

[25] Since the fixed-line regulation index consists of 7 indicators, each of the indicator accounts for about 0.14.

[26] To calculate this we took an average telecommunication investment per capita per year of € 100, which corresponds to some recent reports (OECD Communication Outlook 2007).

6. Conclusion

This study adds to the debate on dynamic — or long-term — effects of the regulatory framework a more careful assessment of the resulting infrastructure investments in the industry. For that purpose an extensive literature review of the debate is provided and an empirical framework, which allows for robust inference given available data, is put forward.

The literature review reveals an important difference between facilities-based and service-based competition as goals for regulatory policies. Most of the commentators are persuaded of the advantages of the facilities-based competition in terms of variety, keen prices and innovation, whereas the service-based competition seems to provide no other benefits than keen prices through the regulator-promoted access. If facilities-based competition is an ultimate goal of proper regulation, then incentives to infrastructure investments become a key measure of success of this regulation. There are conflicting views and research results on the impact of access regulation — leading regulatory solution in the industry — on investments in telecommunications. The majority of the scholars tends to agree, however, that access regulation in fact undermines infrastructure investment, both by incumbents and entrants. This view is also reflected in a recent shift of the Federal Communications Commission (FCC) in the U.S. away from the access regulation.

The empirical analysis of infrastructure investment in telecommunications, which we conduct, is superior to existing studies in several dimensions:

First of all, the dynamics of the investment process are modelled structurally, allowing us to derive short-term and long-term effects of regulation. This approach also fits better to the available investment data (which are on infrastructure level) and allows the results to be linked to a macro-model of growth.

Second, a careful treatment of the endogeneity problem of regulation is proposed by identifying several potential instrumental variables. The following instruments are used for our estimation:

- **Political variables:** Political ideology of the government, attitude of the government toward European integration and attitude of the government toward regulation in general.

- **Neighbouring markets:** We also use levels of regulation in other European countries as possible instruments.

Third, we disaggregate the data so that different effects of regulation in mobile and fixed-line segments of telecommunications, as well as on incumbents and entrants, can be derived. For carrying out such an analysis disaggregated data of the regulatory indicator constructed by Plaut Economics is used along with detailed firm-level infrastructure measures.

Finally, our estimation is based on a comprehensive dataset covering 180 fixed-line and mobile operators in 25 European countries over 10 years. This allows a sample size of the overall regression of around 1000 observations.

Based on this methodology we derive the following main results:

First, estimating a static model (no lagged infrastructure stock variable is included) without controlling for the endogenity problem of regulation results in very different effects than what is found in a richer, statistically more appropriate approach. Using simplified approaches for policy advice can therefore be misleading.

Second, the dynamic specification of the model proves to be correct and robust. The magnitude of the coefficient on the lagged infrastructure variable, which is very close to 1, means that the stock of infrastructure is highly time persistent. It also suggests that shocks to economic determinants of the stock of infrastructure have very persistent effects. A 10% increase in the stock of infrastructure due to a change in some economic conditions is followed by a further 9.4% increase in infrastructure in the next year, 8.8% in two years, 8.3% in three years and so on. The long-term effects are therefore much higher than the immediate effects according to our estimates.

Third, we find that entry regulation discourages infrastructure investment by entrants in fixed-line telecommunications. According to a simulation based on operators in our sample, the introduction of a regulated access to incumbents' networks costs Europe a lost investment in the amount of 25.1% of the entrants' infrastructure stock in the first year. This loss accumulates over time and reaches 111.5%, which is equivalent to €18.1 billion, over 5 years. In other words, our results suggest that the entrants would more than double their infrastructure over 5 years if they had no regulated access to the incumbents' local loops. In terms of the total telecommunication investment in Europe, the lost investment is equivalent to 8.4%, which is a significant amount.

Fourth, incumbents are not found to significantly change their investment as a result of entry regulation in fixed-line telecommunications. One possible explanation of this is that entrants are able to boost end customer demand due to increased variety and innovativeness of their information and communication services offered on incumbents' networks. In this case the lost profit margins of incumbents could be offset by the increase in total demand. It has to be highlighted that the data used for the analysis does not cover investment in next generation access networks. To the extent that the investment in next generation access networks is qualitatively different from upgrading the current infrastructure of incumbents, this result cannot be extrapolated to future investments.

Fifth, while entry regulation significantly discourages investment in fixed-lines by entrants, it seems to have no significant impact on investment in mobile telephony both by entrants and incumbents. This result may be due to the limited quality of the available indicator for entry regulation in mobile telephony, which comprises mainly the number of network-based licences. The number of network-based licences focuses – in contrast to the indicators used for fixed-line telephony - on facility-based entry, for which economic theory predicts significantly different results. But alternative indicators addressing non-facility based entry regulation, like the existence of mobile virtual network operators for instance, are not available.

Overall, the results of this report highlight the importance of using a robust empirical approach if econometric evidence is used for policy advice. Opposite to what is derived from simplified assessments we do not find any indications that entry regulation has a positive impact on investment. On the contrary and in line with the theoretical literature, in the fixed-line sector regulators are faced with an important trade-off, where we find a significant negative effect of entry regulation on the incentives of entrants to invest. Promoting market entry by means of

regulated access might have the desired short-term effect of lower prices and more consumer surplus, but at the same time undermines the incentives of entrants to invest in their own infrastructure and thereby compromising on the long-term goal to establish facilities-based competition.

Appendix 1: The Econometric Model: Derivation

The econometric model that we apply follows Greenstein et al. (1995). It is a partial adjustment model, in which the current infrastructure stock is a weighted average of the long-run desired stock and of the lagged stock value, where the weights reflect the speed of adjustment to long-run equilibrium.

In particular, we assume that $lnfr^*_{kjt}$ reflects the long-run desired stock of infrastructure for firm j in country k in time period t. Let $lnfr^*_{kjt}$ be given by

$$lnfr^*_{kjt} = \boldsymbol{X}_{kjt}\boldsymbol{\beta}' + \varepsilon_{kjt}. \qquad \text{(A1)}$$

For brevity, $\boldsymbol{X}_{kjt}$ comprises all four groups of explanatory variables, as well as the constant term a_0. Current stock levels are given by the adjustment process:

$$lnfr_{kjt} = lnfr_{kjt-1} + a_1'(lnfr^*_{kjt} - lnfr_{kjt-1}) + \mu_{kjt}. \qquad \text{(A2)}$$

Substituting eq. (A1) into eq. (A2), we obtain

$$lnfr_{kjt} = a_1\, lnfr_{kjt-1} + \boldsymbol{X}_{kjt}\boldsymbol{\beta} + v_{kjt}, \qquad \text{(A3)}$$

where $a_1' = 1 - a_1$, $\boldsymbol{\beta}' = \boldsymbol{\beta}/a_1'$ and $v_{kjt} = a_1'\varepsilon_{kjt} + \mu_{kjt}$.

Equation (A3) is identical with equation (1) in the main body of the text. Estimation of eq. (A3) provides information on two aspects of the investment process: First, the estimate of a_1' reflects the speed of adjustment. Second, the estimates of $\boldsymbol{\beta}'$ provide information on the effect of regulatory and economic variables on the long-run desired stock of infrastructure. The estimates of $\boldsymbol{\beta}$ provide the short-run effects.

Appendix 2: List of Companies with Details on Infrastructure Variable

Austria

The geographical markets of the Austrian fixed incumbent Telecom Austria were identified from Osiris. In order to obtain a breakdown at country level, a share of tangible fixed assets in aggregated total assets have been used as a weight to split up the total. Telecom Austria's tangible fixed assets in the fixed-line segment were obtained by subtracting the figures for its mobile subsidiary Mobilkom Austria. Tangible fixed assets at country level for mobile operators Mobilkom Austria and tele.ring Telekom have been drawn from Amadeus.

Table 4: Construction of proxy for infrastructure deployment for the telecom companies in Austria

Country	Segment	Company	Infrastructure	Data source
AT	FIXED	TELEKOM AUSTRIA	Tangible fixed assets in domestic fixed-line market, derived by subtracting the figures for mobile subsidiary	Amadeus Osiris
AT	MOBILE	MOBILKOM AUSTRIA	Tangible fixed assets in domestic mobile market	Amadeus
AT	MOBILE	TELE.RING TELEKOM	Tangible fixed assets in domestic mobile market	Amadeus

Belgium

In Belgium, the figures for Belgacom Mobile were subtracted to obtain figures for the incumbent Belgacom's fixed-line operations. For the fixed entrants and mobile operators disaggregated segment data were available.

Table 5: Construction of proxy for infrastructure deployment for the telecom companies in Belgium

Country	Segment	Company	Infrastructure	Data source
BE	FIXED	BELGACOM	Tangible fixed assets in domestic fixed-line market, derived by subtracting the figures for mobile subsidiary	Amadeus Osiris
BE	FIXED	COLT TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
BE	FIXED	SCARLET TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
BE	FIXED	TELE 2	Tangible fixed assets in domestic fixed-line market	Amadeus
BE	FIXED	TELENET	Tangible fixed assets in domestic fixed-line market	Amadeus
BE	FIXED	VERIZON	Tangible fixed assets in domestic fixed-line market	Amadeus
BE	FIXED	VERSATEL	Tangible fixed assets in domestic fixed-line market	Amadeus
BE	MOBILE	BASE	Tangible fixed assets in domestic mobile market	Amadeus
BE	MOBILE	BELGACOM MOBILE	Tangible fixed assets in domestic mobile market	Amadeus
BE	MOBILE	MOBISTAR	Tangible fixed assets in domestic mobile market	Amadeus Osiris

Bulgaria

Domestic figures for fixed incumbent Bulgarian Telecom include both fixed and mobile telephony operations and cannot be separated.

Table 6: Construction of proxy for infrastructure deployment for the telecom companies in Bulgaria

Country	Segment	Company	Infrastructure	Data source
BE	FIXED	BULGARIAN TELECOM	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus

Czech Republic

Amadeus provides country-level and segment data for telecom companies in the Czech Republic, while the figures for the incumbent Telefonica O2 (Cesky Telecom until 2006) cannot be split into the fixed-line and mobile services segments.

Table 7: Construction of proxy for infrastructure deployment for the telecom companies in the Czech Republic

Country	Segment	Company	Infrastructure	Data source
CZ	FIXED	TELEFONICA O2 (Cesky Telecom)	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus Osiris
CZ	FIXED	GTS NOVERA	Tangible fixed assets in domestic fixed-line market	Amadeus
CZ	FIXED	TELE2	Tangible fixed assets in domestic fixed-line market	Amadeus
CZ	FIXED	TISCALI	Tangible fixed assets in domestic fixed-line market	Amadeus
CZ	FIXED	UPC	Tangible fixed assets in domestic fixed-line market	Amadeus
CZ	FIXED	VERIZON	Tangible fixed assets in domestic fixed-line market	Amadeus
CZ	MOBILE	SKYNET	Tangible fixed assets in domestic mobile market	Amadeus
CZ	MOBILE	T - MOBILE	Tangible fixed assets in domestic mobile market	Amadeus
CZ	MOBILE	VODAFONE	Tangible fixed assets in domestic mobile market	Amadeus

Denmark

Domestic figures provided for the Denmark's fixed incumbent TDC have been split by subtracting the according values for mobile subsidiary TDC Mobil in order to identify its fixed-line operation. Data for entrants and mobile companies are those for country-level.

Table 8: Construction of proxy for infrastructure deployment for the telecom companies in Denmark

Country	Segment	Company	Infrastructure	Data source
DK	FIXED	TDC	Tangible fixed assets in domestic fixed-line market, derived by subtracting the figures for mobile subsidiary	Amadeus
DK	FIXED	COLT TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
DK	FIXED	TELE2	Tangible fixed assets in domestic fixed-line market	Amadeus
DK	FIXED	VERIZON	Tangible fixed assets in domestic fixed-line market	Amadeus
DK	MOBILE	DEBITEL	Tangible fixed assets in domestic mobile market	Amadeus
DK	MOBILE	SONOFON	Tangible fixed assets in domestic mobile market	Amadeus
DK	MOBILE	TDC MOBIL	Tangible fixed assets in domestic mobile market	Amadeus
DK	MOBILE	TELIA	Tangible fixed assets in domestic mobile market	Amadeus

Estonia

Amadeus provides data for the fixed incumbent Elion Ettevotted and fixed entrant Tele2 on domestic fixed-line operations.

Table 9: Construction of proxy for infrastructure deployment for the telecom companies in Estonia

Country	Segment	Company	Infrastructure	Data source
EE	FIXED	ELION ETTEVÕTTED	Tangible fixed assets in domestic fixed-line market	Amadeus
EE	FIXED	TELE2	Tangible fixed assets in domestic fixed-line market	Amadeus

France

In France, aggregated tangible assets of the fixed incumbent France Telecom show a breakdown using geographical market data provided by Osiris. Figures for France Telecom for all countries in which the company operates have been weighted by shares of tangible fixed assets in aggregated total assets to give data for domestic market. Data for France Telecom Mobile have been subtracted in order to gain the figures for fixed-line activity. Data for the remaining market players are those for domestic segment levels correspondingly.

Table 10: Construction of proxy for infrastructure deployment for the telecom companies in France

Country	Segment	Company	Infrastructure	Data source
FR	FIXED	FRANCE TELECOM	Tangible fixed assets in domestic fixed-line market, derived by subtracting the figures for mobile subsidiary	Amadeus Osiris
FR	FIXED	AFONE	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
FR	FIXED	BT C & SI	Tangible fixed assets in domestic fixed-line market	Amadeus
FR	FIXED	BUDGET TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
FR	FIXED	COLT TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
FR	FIXED	INTERCALL	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
FR	FIXED	NEUF CEGETEL	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
FR	FIXED	PHONE SYSTEMS	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
FR	FIXED	TELECOM ITALIA	Tangible fixed assets in domestic fixed-line market	Amadeus
FR	FIXED	TELEMEDIA	Tangible fixed assets in domestic fixed-line market	Amadeus
FR	FIXED	TISCALI	Tangible fixed assets in domestic fixed-line market	Amadeus
FR	FIXED	VERIZON	Tangible fixed assets in domestic fixed-line market	Amadeus
FR	MOBILE	BOUYGUES TELECOM	Tangible fixed assets in domestic mobile market	Amadeus
FR	MOBILE	DEBITEL	Tangible fixed assets in domestic mobile market	Amadeus
FR	MOBILE	FRANCE TELECOM MOBILE	Tangible fixed assets in domestic mobile market	Amadeus
FR	MOBILE	GENESYS	Tangible fixed assets in domestic mobile market	Amadeus Osiris
FR	MOBILE	INDEX MULTIMEDIA	Tangible fixed assets in domestic mobile market	Amadeus Osiris
FR	MOBILE	ORANGE FRANCE	Tangible fixed assets in domestic mobile market	Amadeus
FR	MOBILE	SFR (Vodafone)	Tangible fixed assets in domestic mobile market	Amadeus
FR	MOBILE	T-ONLINE	Tangible fixed assets in domestic mobile market	Amadeus

Germany

In Germany, the figures for the incumbent Deutsche Telekom have been calculated from total tangible fixed assets and split up by weighting using a share of tangible fixed assets in aggregated total assets. The data on geographical markets were derived from Osiris. Figures for Deutsche Telekom and its mobile subsidiary T-Mobile have been separated at country level through subtraction. Country-level data for entrants and mobile operators in Germany were collected from Amadeus.

Table 11: Construction of proxy for infrastructure deployment for the telecom companies in Germany

Country	Segment	Company	Infrastructure	Data source
DE	FIXED	DEUTSCHE TELEKOM	Tangible fixed assets in domestic fixed-line market, derived by subtracting the figures for mobile subsidiary	Amadeus Osiris
DE	FIXED	3U TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
DE	FIXED	ARCOR	Tangible fixed assets in domestic fixed-line market	Amadeus
DE	FIXED	COLT TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
DE	FIXED	FREENET	Tangible fixed assets in domestic fixed-line market	Amadeus
DE	FIXED	TISCALI	Tangible fixed assets in domestic fixed-line market	Amadeus
DE	FIXED	VERIZON	Tangible fixed assets in domestic fixed-line market	Amadeus
DE	FIXED	VERSATEL	Tangible fixed assets in domestic fixed-line market	Amadeus
DE	MOBILE	DRILLISCH	Tangible fixed assets in domestic mobile market	Amadeus
DE	MOBILE	E-PLUS	Tangible fixed assets in domestic mobile market	Amadeus
DE	MOBILE	O2	Tangible fixed assets in domestic mobile market	Amadeus
DE	MOBILE	T-MOBILE	Tangible fixed assets in domestic mobile market	Amadeus
DE	MOBILE	VODAFONE	Tangible fixed assets in domestic mobile market	Amadeus

Greece

Disaggregated data at country and segment levels for telecom operators in Greece were obtained from Amadeus.

Table 12: Construction of proxy for infrastructure deployment for the telecom companies in Greece

Country	Segment	Company	Infrastructure	Data source
GR	FIXED	OTE GLOBE	Tangible fixed assets in domestic fixed-line market	Amadeus
GR	FIXED	FORTHNET	Tangible fixed assets in domestic fixed-line market	Amadeus
GR	FIXED	HELLAS ON LINE	Tangible fixed assets in domestic fixed-line market	Amadeus
GR	FIXED	NEWSPHONE	Tangible fixed assets in domestic fixed-line market	Amadeus
GR	FIXED	VERIZON	Tangible fixed assets in domestic fixed-line market	Amadeus
GR	MOBILE	COSMOTELCO	Tangible fixed assets in domestic mobile market	Amadeus
GR	MOBILE	Q TELECOM	Tangible fixed assets in domestic mobile market	Amadeus

Hungary

Country-level data for telecom companies in Hungary were drawn from Amadeus. While figures for Magyar Telekom, Hungary's fixed incumbent, cannot be split in fixed-line and mobile operations, the figures for the remaining companies are for segments correspondingly.

Table 13: Construction of proxy for infrastructure deployment for the telecom companies in Hungary

Country	Segment	Company	Infrastructure	Data source
HU	FIXED	MAGYAR TELEKOM	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus
HU	FIXED	HUNGAROTEL	Tangible fixed assets in domestic fixed-line market	Amadeus
HU	FIXED	INVITEL	Tangible fixed assets in domestic fixed-line market	Amadeus
HU	FIXED	UPC	Tangible fixed assets in domestic fixed-line market	Amadeus
HU	MOBILE	PANNON GSM	Tangible fixed assets in domestic mobile market	Amadeus
HU	MOBILE	VODAFONE	Tangible fixed assets in domestic mobile market	Amadeus

Ireland

Splitting of domestic figures for the fixed incumbent Eircom between operational segments was not feasible. Data on domestic core operations were identified for fixed entrants and mobile telephony companies.

Table 14: Construction of proxy for infrastructure deployment for the telecom companies in Ireland

Country	Segment	Company	Infrastructure	Data source
IE	FIXED	EIRCOM	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus Osiris
IE	FIXED	BT	Tangible fixed assets in domestic fixed-line market	Amadeus
IE	FIXED	COLT TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
IE	FIXED	ENERGIS	Tangible fixed assets in domestic fixed-line market	Amadeus
IE	MOBILE	METEOR MOBILE	Tangible fixed assets in domestic mobile market	Amadeus
IE	MOBILE	O2	Tangible fixed assets in domestic mobile market	Amadeus
IE	MOBILE	VODAFONE	Tangible fixed assets in domestic mobile market	Amadeus

Italy

Amadeus provides country-level data for telecom segments in Italy.

Table 15: Construction of proxy for infrastructure deployment for the telecom companies in Italy

Country	Segment	Company	Infrastructure	Data source
IT	FIXED	TELECOM ITALIA	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	FIXED	FASTWEB	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	FIXED	TELE2	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	FIXED	TISCALI	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	FIXED	WIND	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	MOBILE	TIM ITALIA	Tangible fixed assets in domestic mobile market	Amadeus
IT	MOBILE	VODAFONE GESTIONI	Tangible fixed assets in domestic mobile market	Amadeus
IT	MOBILE	VODAFONE OMNITEL	Tangible fixed assets in domestic mobile market	Amadeus

Latvia

In Latvia, data for telecom companies were disaggregated figures at country and segment levels.

Table 16: Construction of proxy for infrastructure deployment for the telecom companies in Latvia

Country	Segment	Company	Infrastructure	Data source
IT	FIXED	LATTELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	FIXED	TELEKOM BALTIJA	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	FIXED	TELEKOMUNIKACIJU GRUPA	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	MOBILE	LATVIJAS MOBILAIS	Tangible fixed assets in domestic mobile market	Amadeus
IT	MOBILE	TELE2	Tangible fixed assets in domestic mobile market	Amadeus

Lithuania

For the fixed telephony companies Lietuvos Telekomas and TEO domestic figures have been identified. Data for the incumbent Lietuvos Telekomas include other operations in addition to fixed-line telephony.

Table 17: Construction of proxy for infrastructure deployment for the telecom companies in Lithuania

Country	Segment	Company	Infrastructure	Data source
LV	FIXED	LIETUVOS TELEKOMAS	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus
LV	FIXED	TEO	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris

Luxemburg

Figures for mobile telephony companies in Luxembourg relate to domestic mobile services.

Table 18: Construction of proxy for infrastructure deployment for the telecom companies in Luxembourg

Country	Segment	Company	Infrastructure	Data source
LU	MOBILE	CEGECOM WIRELESS	Tangible fixed assets in domestic mobile market	Amadeus
LU	MOBILE	LUXGSM	Tangible fixed assets in domestic mobile market	Amadeus
LU	MOBILE	MILLICOM CELLULAR	Tangible fixed assets in domestic mobile market	Amadeus Osiris
LU	MOBILE	TANGO	Tangible fixed assets in domestic mobile market	Amadeus
LU	MOBILE	VOXMOBILE	Tangible fixed assets in domestic mobile market	Amadeus

Malta

Figures for the fixed incumbent Maltacom were those for the domestic market; the separation into market segments was unfeasible. Country-level data has been used for mobile service companies.

Table 19: Construction of proxy for infrastructure deployment for the telecom companies in Malta

Country	Segment	Company	Infrastructure	Data source
IT	FIXED	MALTACOM	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus
IT	MOBILE	MOBISLE COMMUNICATIONS	Tangible fixed assets in domestic mobile market	Amadeus
IT	MOBILE	VODAFONE	Tangible fixed assets in domestic mobile market	Amadeus

Netherlands

According to geographical segmentation provided by Osiris a breakup of aggregate figures was necessary for the fixed incumbent KPN and fixed entrant Versatel, where shares of tangible assets were used. Consequently, figures for KPN Mobile were subtracted in order to obtain the segment operation in fixed-line for the incumbent. The remaining figures describe core operations in the domestic market correspondingly.

Table 20: Construction of proxy for infrastructure deployment for the telecom companies in the Netherlands

Country	Segment	Company	Infrastructure	Data source
IT	FIXED	KPN	Tangible fixed assets in domestic fixed-line market, derived by subtracting the figures for mobile subsidiary	Amadeus Osiris
IT	FIXED	TELE2	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	FIXED	UPC	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	FIXED	VERSATEL	Tangible fixed assets in domestic fixed-line market	Amadeus
IT	MOBILE	KPN MOBILE	Tangible fixed assets in domestic mobile market	Amadeus
IT	MOBILE	ORANGE	Tangible fixed assets in domestic mobile market	Amadeus

Poland

In Poland, the data for the fixed incumbent Telekomunikacja Polska provides figures for both fixed-line and mobile services; the separation was not feasible. Disaggregated data was obtained for fixed entrants and mobile operators.

Table 21: Construction of proxy for infrastructure deployment for the telecom companies in Poland

Country	Segment	Company	Infrastructure	Data source
PL	FIXED	TELEKOMUNI-KACJA POLSKA	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus Osiris
PL	FIXED	NETIA	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
PL	FIXED	TELE2	Tangible fixed assets in domestic fixed-line market	Amadeus
PL	MOBILE	CENTERTEL POLSKA TELEFONIA	Tangible fixed assets in domestic mobile market	Amadeus
PL	MOBILE	POLKOMTEL	Tangible fixed assets in domestic mobile market	Amadeus
PL	MOBILE	POLSKA TELEFONIA CYFROWA	Tangible fixed assets in domestic mobile market	Amadeus

Portugal

Data for core operations in the domestic telecom market for the fixed incumbent PT Comunicacoes as well as for the fixed entrants and mobile service firms have been identified.

Table 22: Construction of proxy for infrastructure deployment for the telecom companies in Portugal

Country	Segment	Company	Infrastructure	Data source
PT	FIXED	PT COMUNI-CAÇOES	Tangible fixed assets in domestic fixed-line market	Amadeus
PT	FIXED	NOVIS TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
PT	MOBILE	OPTIMUS TELECOM	Tangible fixed assets in domestic mobile market	Amadeus
PT	MOBILE	TMN TELECOM	Tangible fixed assets in domestic mobile market	Amadeus
PT	MOBILE	VODAFONE	Tangible fixed assets in domestic mobile market	Amadeus

Romania

Aggregated data at domestic level for the incumbent Romtelecom cannot be split, whereas segment data has been collected for remaining market players.

Table 23: Construction of proxy for infrastructure deployment for the telecom companies in Romania

Country	Segment	Company	Infrastructure	Data source
RO	FIXED	ROMTELECOM	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus
RO	FIXED	UPC	Tangible fixed assets in domestic fixed-line market	Amadeus
RO	MOBILE	COSMOTE MOBILE	Tangible fixed assets in domestic mobile market	Amadeus
RO	MOBILE	MOBIFON SA	Tangible fixed assets in domestic mobile market	Amadeus
RO	MOBILE	ORANGE	Tangible fixed assets in domestic mobile market	Amadeus

Slovakia

For telecom companies in Slovakia segment figures for domestic market have been identified.

Table 24: Construction of proxy for infrastructure deployment for the telecom companies in Slovakia

Country	Segment	Company	Infrastructure	Data source
SK	FIXED	SLOVANET	Tangible fixed assets in domestic fixed line market	Amadeus
SK	MOBILE	ORANGE	Tangible fixed assets in domestic mobile market	Amadeus
SK	MOBILE	T - MOBILE	Tangible fixed assets in domestic mobile market	Amadeus

Slovenia

For the incumbent Telekom Slovenije a separation of domestic figures into sub-operations was not feasible. Domestic figures for mobile operators were drawn from Amadeus.

Table 25: Construction of proxy for infrastructure deployment for the telecom companies in Slovenia

Country	Segment	Company	Infrastructure	Data source
SI	FIXED	TELEKOM SLOVENIJE	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus
SI	MOBILE	MOBITEL	Tangible fixed assets in domestic fixed-line market	Amadeus
SI	MOBILE	SI.MOBIL TELEKOM	Tangible fixed assets in domestic mobile market	Amadeus
SI	MOBILE	WESTERN WIRELESS	Tangible fixed assets in domestic mobile market	Amadeus

Spain

Disaggregated data at country and segment levels has been identified for the telecom operators in Spain.

Table 26: Construction of proxy for infrastructure deployment for the telecom companies in Spain

Country	Segment	Company	Infrastructure	Data source
ES	FIXED	TELEFONICA	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	BT	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	EUSKALTEL	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	ONO	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	JAZZ TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	TELE2	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	TENARIA	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	MOBILE	TELEFONICA MOVILES	Tangible fixed assets in domestic mobile market	Amadeus
ES	MOBILE	T-ONLINE TELECOM	Tangible fixed assets in domestic mobile market	Amadeus
ES	MOBILE	VODAFONE	Tangible fixed assets in domestic mobile market	Amadeus

Sweden

For the fixed incumbent Teliasonera Sverige and its subsidiary Teliasonera Mobile as well as for the remaining telecom operators the country-level data for core operations has been obtained.

Table 27: Construction of proxy for infrastructure deployment for the telecom companies in Sweden

Country	Segment	Company	Infrastructure	Data source
ES	FIXED	TELIASONERA SVERIGE	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	TELE2	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	TELENOR	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	FIXED	VERIZON	Tangible fixed assets in domestic fixed-line market	Amadeus
ES	MOBILE	SPRING MOBIL	Tangible fixed assets in domestic mobile market	Amadeus
ES	MOBILE	TELIASONERA MOBILE	Tangible fixed assets in domestic mobile market	Amadeus

United Kingdom

In the United Kingdom, domestic figures for the fixed incumbent BT and mobile operator Vodafone have been reached by weighting domestic total assets by the share of tangible fixed assets in aggregated total assets. Data for geographical markets provided by Osiris has been deployed. While the separation of domestic figures for BT was not feasible, disaggregated data for the rest of telecom companies was available.

Table 28: Construction of proxy for infrastructure deployment for the telecom companies in the United Kingdom

Country	Segment	Company	Infrastructure	Data source
GB	FIXED	BT	Tangible fixed assets in domestic market, include both fixed-line and mobile operations	Amadeus Osiris
GB	FIXED	ADEPT TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
GB	FIXED	ALTERNATIVE NETWORKS	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
GB	FIXED	BNS TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
GB	FIXED	COLT	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	FIXED	KINGSTON	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	FIXED	NTL	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	FIXED	PIPEX	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	FIXED	PNC TELECOM	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
GB	FIXED	SPECTRUM INTERACTIVE	Tangible fixed assets in domestic fixed-line market	Amadeus Osiris
GB	FIXED	TELECOM PLUS	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	FIXED	TELEPHONE MAINTENANCE	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	FIXED	TELEWEST	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	FIXED	THUS	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	FIXED	VANCO	Tangible fixed assets in domestic fixed-line market	Amadeus
GB	MOBILE	2 ERGO	Tangible fixed assets in domestic mobile market	Amadeus
GB	MOBILE	AXISMOBILE	Tangible fixed assets in domestic mobile market	Amadeus Osiris
GB	MOBILE	GETMOBILE	Tangible fixed assets in domestic mobile market	Amadeus Osiris
GB	MOBILE	HUTCHISON 3G	Tangible fixed assets in domestic mobile market	Amadeus
GB	MOBILE	MOBESTAR	Tangible fixed assets in domestic mobile market	Amadeus
GB	MOBILE	MOBILE STREAMS	Tangible fixed assets in domestic mobile market	Amadeus Osiris
GB	MOBILE	O2	Tangible fixed assets in domestic mobile market	Amadeus
GB	MOBILE	ORANGE	Tangible fixed assets in domestic mobile market	Amadeus
GB	MOBILE	SATCOM	Tangible fixed assets in domestic mobile market	Amadeus Osiris
GB	MOBILE	SPIRITEL	Tangible fixed assets in domestic mobile market	Amadeus Osiris
GB	MOBILE	T-MOBILE	Tangible fixed assets in domestic mobile market	Amadeus
GB	MOBILE	VODAFONE	Tangible fixed assets in domestic mobile market	Amadeus

Appendix 3: The Econometric Model: Alternative Specifications

To check the robustness of our results we run additional IV regressions including a full set of explanatory variables. The results in Table 29 show that they are generally robust to inclusion of the cost shifters and competition measures as additional explanatory variables. Because of missing observations, which tend not to show in these variables, however, our sample size drops from 730 to 445 observations and some statistical significance is lost.

Table 29 reports also two additional statistics, which test whether our model is properly specified. Hansen J's statistic is used to test the overidentifying restrictions of the model. The statistics are insignificant in all four regressions suggesting that the instrumental variables that we used in the regressions are exogenous. Moreover, in the first stage of regressions (not reported here) the instruments explain a significant part of variation in the regulatory variables, which further justify their use as proper instruments.

The second test that we performed consists of including lagged residual into the regression. The aim of the test is to detect serial correlation in the error term, which indicates a misspecification of the model. The lagged residuals are not significant in all four regressions in Table 29, which suggests no serial correlation in the dynamic model.

The next set of results in Table 30 compares the performance of a dynamic model (columns 1 and 2) and a static model (columns 3 and 4). The estimates in the first column of Table 30 are the same as in Table 29 and Table 3. The second column contains results of the same model estimated by OLS. The results in column 1 and column 2 are not statistically different. Accounting for the possible endogeneity of regulation does not alter the results of the dynamic model. This is in strong contrast to the static model. Estimated by OLS the static model shows very different coefficients than the dynamic model. In particular, all regulatory variables seem to have a significant positive impact on infrastructure deployment. This positive effect of regulation disappears in the IV regression in column 4. Inspection of the static model's test statistics also reveals a strong serial correlation in the error term, as evidenced by large and significant coefficients on the lagged residual, and Hansen J's statistics are significantly different from 0. In sum, the static model seems to suffer from omitted variables, which are time persistent and bias the coefficients on regulatory variables. The IV techniques help to alleviate the problem to some extent. In any case, the dynamic model proves superior to the static model.

Table 29: Dynamic Model of Investment: Instrumental Variables (IV)
Estimation Results of Alternative Models

Dependent variable: Log(Infr)

	(1)	(2)	(3)	(4)
Log(Infr) (-1)	0.94***	0.95**	0.95***	0.96***
	(0.02)	(0.02)*	(0.01)	(0.01)
Mobile	-0.63	-0.52	-1.09**	-0.80
	(0.49)	(0.56)	(0.48)	(0.51)
Incumb	-0.41***	-0.40***	-0.51***	-0.49***
	(0.08)	(0.08)	(0.13)	(0.14)
Multisec	0.27**	0.31**	0.46***	0.50***
	(0.12)	(0.13)	(0.17)	(0.19)
Log(M&A) * I(M&A)	0.04**	0.04**	0.04*	0.04**
	(0.02)	(0.02)	(0.02)	(0.02)
Log(GDPpc)	0.52**	0.46*	0.22	0.64
	(0.26)	(0.26)	(0.39)	(0.59)
EntryFix[1] * Incumb	-0.02	0.00	-0.16	-0.08
	(0.21)	(0.22)	(0.29)	(0.28)
EntryFix[1] * Entrant	-0.44***	-0.36**	-0.43*	-0.29
	(0.15)	(0.17)	(0.25)	(0.23)
EntryMob[1] * Mobile	0.87	0.73	1.69**	1.23
	(0.82)	(0.91)	(0.78)	(0.81)
Log(Labour)		0.14		0.57
		(0.41)		(1.16)
Debt (-1)		-0.04		-0.02
		(0.05)		(0.06)
Log(PopDens)		-2.50		-4.37
		(1.95)		(4.32)
CompMob			0.36	0.21
			(0.42)	(0.44)
CompFix			0.00	0.00
			(0.00)	(0.00)
Hansen J statistic (Chi-sq(9))	7.31	7.26	6.21	6.23
Residual (-1)	0.05	0.02	-0.02	-0.04
	(0.05)	(0.05)	(0.05)	(0.05)
Observations	730	635	500	445
R-squared	0.96	0.96	0.96	0.96

Notes:
Robust standard errors in parentheses.
The estimates for intercept, country-specific effects and year dummies are not shown.
* Significant at 10%; ** significant at 5%; *** significant at 1%.
[1] Endogenous variables: EntryFix and EntryMobl; Instrumental variables: EntryFixNeighbour, EntryMobNeighbour, Regul, Rile, Europ and interactions thereof.

Table 30: Dynamic vs. Static Model of Investment: Estimation Results

Dependent variable: Log(Infr)

	(1)	(2)	(3)	(4)
	IV	OLS	OLS	IV
Log(Infr) (-1)	0.94***	0.95***		
	(0.02)	(0.01)		
Mobile	-0.63	-0.21	0.77	3.00
	(0.49)	(0.16)	(0.72)	(3.22)
Incumb	-0.41***	-0.42***	0.48	0.82
	(0.08)	(0.09)	(0.56)	(1.24)
Multisec	0.27**	0.25**	2.85***	2.66**
	(0.12)	(0.11)	(0.47)	(1.16)
Log(M&A) * I(M&A)	0.04**	0.03	0.10	0.10*
	(0.02)	(0.02)	(0.07)	(0.06)
Log(GDPpc)	0.52**	0.30	-1.20	-1.38
	(0.26)	(0.21)	(1.01)	(0.92)
EntryFix[1] * Incumb	-0.02	-0.01	3.26***	2.96
	(0.21)	(0.16)	(0.95)	(1.84)
EntryFix[1] * Entrant	-0.44***	-0.50***	1.70***	1.42
	(0.15)	(0.14)	(0.55)	(1.07)
EntryMob[1] * Mobile	0.87	-0.01	3.17***	-0.83
	(0.82)	(0.21)	(1.11)	(5.31)
Hansen J statistic (Chi-sq(9))	7.31	-	-	16.6*
Residual (-1)	0.05	0.06	0.93***	0.94***
	(0.05)	(0.05)	(0.01)	(0.02)
Observations	730	867	1083	935
R-squared	0.96	0.96	0.34	0.32

Notes:
Robust standard errors in parentheses.
The estimates for intercept, country-specific effects and year dummies are not shown.
* Significant at 10%; ** significant at 5%; *** significant at 1%.
[1] Endogenous variables: EntryFix and EntryMob; Instrumental variables: EntryFixNeighbour, EntryMobNeighbour, Regul, Rile, Europ and interactions thereof.

Appendix 4 References

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