Regulation and Investments in Telecommunication Markets

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– Preliminary Version, please do not quote. –

Abstract With the technological improvements in data transmission the importance of telecommunications for other industries has crucially changed. Telecommunication operators can only partially internalize the growing importance of telecommunications by providing tailored offers to specific demand groups, thus reducing their congestions. Governmental interventions therefore should address multi-market effects in particular of key sectors. Thus, considering only the direct impact of interventions on the outcome of a particular market under scrutiny ignores both spill-overs from regulations to other markets and additionally externalities which can not sufficiently be internalized by operators in the market under regulators' scrutiny. This paper empirically analyzes the impact of governmental intervention in EU 15 fixed line service and mobile service markets.

Keywords regulation, telecommunications, innovation, inter-market relationships
JEL Classification L51, L52, L86, L96, O31, O33

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1 Introduction

During the last 10 to 15 years European ICT markets have experienced their most extensive transformation since the early beginnings of telephony. Innovations in communication technology like digital data transmission and the World Wide Web provided access to a new generation of information provision. Thus the internet became available not only to professional ICT users and institutions but also to households. The rapid growth of the "digital world" has enabled new market models, e.g. two-sided markets, where the internet itself serves as the common platform for communication.
Alongside the technological progress a change in political and institutional thinking has taken place. One important outcome of this new "European Spirit" is the liberalization of network based markets in all EU member states. By 1998 at the latest, former European telecommunication monopolists had to open all national telecommunication markets to competitors. In anticipation of this change, during the first half of the 1990s national competition and telecommunication agencies liberalized the cellular mobile communication markets by selling or assigning new broadcasting frequencies.
Both the technological and the institutional changes on telecommunication markets have had comprehensive consequences for daily life and for economic development and caused a new kind of B2B (business to business)- and B2C (business to consumer) - communication. Since the end of the 1990s enterprizes from all sectors have adapted to new communication opportunities and have changed business processes as a result of more flexibility in communications.
Continuous observations, e.g. the ZEW ICT survey, trace the growing importance of ICT in particular for knowledge based industries. Like no other sector, ICT was and is gaining in importance, not only altering the outcome of ICT markets themselves, but also resulting in adjustments in the behavior of firms in other sectors.
The traditional one-market regulation perspective is employed to enhance the outcome of a market under scrutiny but completely ignores multi-industry consequences. In markets where spill-overs into other industries are small, one-market regulation is the most efficient approach. But intervention in industries with complex integration with other industries requires comprehensive consideration of cross-industry effects. In contrast to the intervention on other network based markets, controlling telecommunications is very difficult in particular because of these spill-overs to other industries. Consequently, governmental interventions in telecommunications have to be implemented very carefully.
My analysis of telecommunication regulation follows a two-step long-run procedure. I first consider the growing importance of telecommunication as an input factor for other industries and descriptively show the change in relevance of telecommunication. The second part relates to the impact of deregulating access to telecommunication service markets on telecommunication investments.
In chapter 2 I give an overview of current literature on the link between regulation, telecommunication and innovation. Chapter 3 provides an analysis of the steps to total telecommunication liberalization. Additionally, I take a look at the relevance of telecommunication for other industries and finally describe the change in the importance of telecommunication investments. Chapter 4 explains the hypotheses concerning

liberalization and service market spill-overs. Afterwards an overview of the data generation and modification process and the underlying database is given. Chapter 6 provides an econometric analysis of the hypotheses. Chapter 7 concludes.

2 Related Studies on Regulation, Telecommunication and Innovation

Empirical work on regulation, investments and innovations in telecommunication markets mainly concentrates on one-market examinations. Wallsten (2001) analyzes in a cross-countries panel-data setup how infrastructure liberalization and privatization affect investment patterns. He uses data for African and Latin-American countries and identifies a positive correlation of competition on mainline penetration and connection capacity. On the other hand privatization does not have any positive effect and prices are driven down by increasing competition.
In a subsequent study Wallsten takes a closer look at the sequence of privatization and deregulation (Wallsten (2002)). He comes to the conclusion that, if liberalization follows privatization, this decreases market concentration and market power of the former monopolistic firm more strongly than the other way round.
Duso and Roeller (2003) provide results on the strategic behavior of incumbent firms facing changes in the regulation pattern. In a cross-country analysis of OECD countries they find that strategic adjustments to regulation are also made in times other than after the implementation of new governmental interventions. Furthermore, incumbent operators observe and try to influence the steps to new regulation, thus anticipating the forthcoming interventions, and adopt their expectations to their investment decisions.
In a very recent paper, Friederiszick and Roeller (2007) argue that only a sufficiently long observation period could cover all effects in a highly volatile and innovative market environment. Pre-drawing effects and technological changes otherwise cannot be taken into account. Therefore, Friederiszick and Roeller recommend a flexible setup and strongly argue for a large database.[1]
In a macroeconomic multi-market setup of 21 OECD countries Waverman and Roeller (2001) empirically analyze the impact of investments in telecommunication assets on the development of GDP. A problem mentioned in this context stems from causality. As Waverman and Roeller explain, telecommunication investments support investments in other industries because opportunities such as faster data transmission enable a more contemporaneous implementation of new strategies. Thus increasing transmission quality in telecommunications results both in an increase in product quality and accelerates the process of bringing new goods to the markets. In line with this argumentation an increase in telecommunication investments should increase total income.
On the other hand, total income might drive higher investments in telecommunications.

[1] This paper addresses the PricewaterhouseCoopers 2006 report for the European Commission. The report analyzes the effects of the 2002 interventions to protect competition in European telecommunication markets.

In the Waverman and Roeller panel data set nearly all telecommunication firms are state-controlled. Thus an increase in GDP leads to an increase in state budget levels and, therefore, facilitates investment in telecommunications.[2]
Taking into account the approach taken by Waverman and Roeller, the recommendations made by Friederiszick and Roeller, and Wallsten's approach and findings, I analyze the impact of liberalization in telecommunications on investments and the influence of telecommunication services on investment behavior.[3]

3 Theoretical Background

3.1 Telecommunications and Governmental Intervention

The ongoing European integration after the Cold War strengthened the political and economic power of European countries as a whole. One major requirement for this coalescence was transferring political power and responsibility from a national level to super-ordinated European institutions.
During the 1990s one of the most important changes in European competition law were the stepwise liberalization and accompanying regulation of former state-controlled network-based markets.[4] In telecommunications the liberalization procedure started with the 1988 directive on competition in the markets in telecommunications terminal equipment (88/301/ EEC). This directive accommodates competition on the markets for terminal equipment by making publicly available information to fit transmission standards. The Service Directive 90/388/EEC of 1990 restricted the monopolies to voice telephony and networks and opened the markets for data transmission. Directive 95/51/EC allowed for competition between infrastructures by opening cable infrastructure for the transmission of information. But the ownership of the cable infrastructure still remained at the former monopolists.
The most important guideline was the 1996 Competition Directive 96/19/EC which opened both the markets for infrastructure and the markets for voice transmission to potential competitors. In most EU 15 countries this guideline was implemented to national law in 1998.[5]

[2] This argumentation is of causal interest in the analysis of the impact of regulation. The database underlying this paper covers two different periods of time: Before the 1990s (nearly) all telecommunication suppliers under scrutiny were state-controlled. In line with the liberalization process in many countries the former monopolists were restructured and at least some shares of the firms are sold to interested groups. Therefore, the direct governmental control of the former monopolists shrinks.

[3] In a subsequent study I complement the findings of this paper by an econometric cross-sector analysis of spill-overs on other markets which are affected by telecommunications modifications.

[4] Appendix 4 summarizes the main figures of revenue and infrastructure changes between 1990 and 2004.

[5] All in all about 20 liberalization guidelines had come into force by 2002. These have complemented these first directives and accommodated their contents with regard to technological improvements. In line with the Liberalization Directives the so-called Harmonization Directives were implemented to guarantee a homogeneous transition to national law in all European countries.

As a consequence of these liberalization policies, newly available communication technologies, e.g. email or other forms of messaging based on digital transmission systems, were made useable for a broader range of people. Since the late 1980s the combination of technological and institutional changes has made electronic communication more affordable and has led to an interactive acceleration. While technological progress in telecommunications was (and is) driven by global development and by ICT deployment, institutional changes are bound to national or regional social and political changes and thus were mainly a consequence of the European situation per se.[6]
While in all other European countries the liberalization took place in 1998 at the earliest, the U.K., Sweden, Finland, the Netherlands and Denmark allowed competitors to enter the markets before 1996.
In the first half of the 1990s many European countries took a significant step towards competition in mobile phone markets on their own initiative by offering additional transmission frequencies for mobile communication, above and beyond the existent incumbents' frequencies.[7] Until the end of the 1990s – in particular in line with the implementation of the Mobile Directive 96/2/EC – in most European countries additional licences were assigned so that – usually – four different network operators hold transmission capacities on two different frequency levels.
Accompanying the steps to more competition, telecommunication markets have experienced a wave of privatization activities in all European countries since the second half of the 1990s. States kept ownership of a large share of the (former) monopolists and sold/ are selling their ownership rights stepwise.
In line with the *Communication Review* of 1999 the European Commission has developed a new regulatory framework which represents the transition from the phase of beginning competition in all telecommunication markets to a phase of ensuring competition. In 2002 these directives came into force. The 1990s directives were consolidated in one liberalization directive and five harmonization directives.[8]

3.2 Telecommunication Revenue and Investment

From the early 1990s until the burst of the technology bubble in 2000 a strong increase in telecommunications revenue relative to total GDP is observable, not only as a single European effect but worldwide. Even after 2000 the level of outcome remains at its higher relative position. Two main influences can be identified which go hand in hand: the reduction of state control and the importance of ICT for other industries. Figure 1 displays total telecommunications revenue in relation to GDP. In opposite to the states of comparison we can identify a continuously growing relevance of telecommunications

[6] Nevertheless, during the 1990s a re-think of regulation and state control of economic activities took place all over the world. E.g. the two most famous changes in U.S. telecommunication institutional thinking were the divestiture of AT&T, the former long-distance monopolist in the U.S., and the 1996 Telecommunications Act, a complete revision of the U.S. Telecommunication laws which were in place for 62 years.
[7] One main exception was the U.K. where new frequencies were already offered in 1985.
[8] Directives 2002/19/EC - 2002/22/EC, 2002/77/EC

Figure 1: Total Telecommunications Revenue in Relation to GDP[9]

for the EU 15 countries.[10]

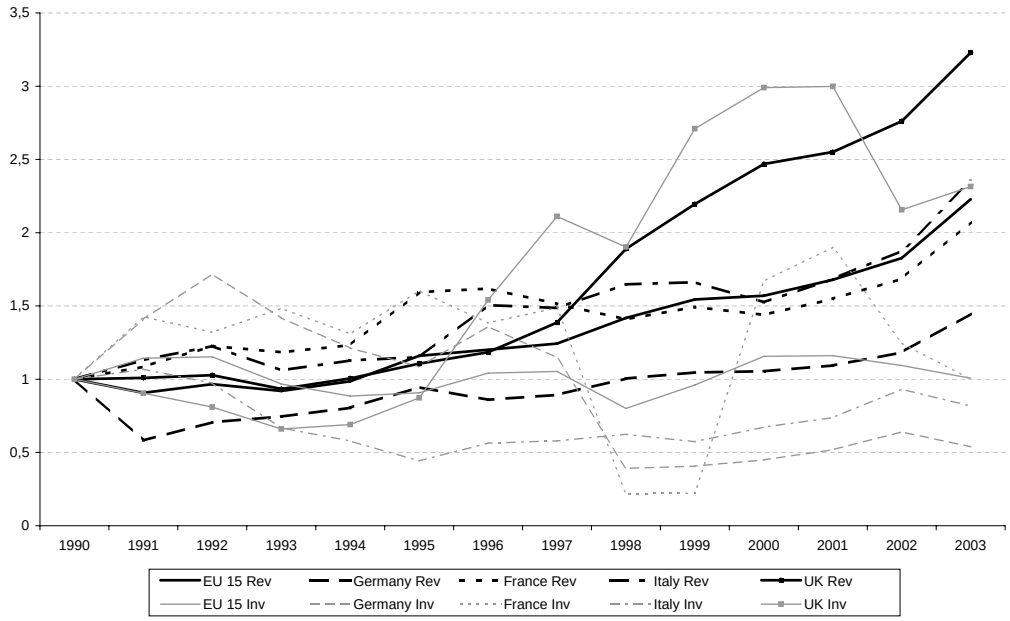
For a sustainable increase of telecommunication revenue in relation to GDP we should expect to see investments in telecommunications growing in at least a similar pattern to revenues. To check this fundamental assumption I have plotted public telecommunication operators' (PTO) revenues and investments relative to the 1990 levels. The results for the four largest European countries depending on per capita GDP – France, Germany, Italy and the UK – can be found in figure 2. Bold lines represent revenue and fine lines investments. For all countries under scrutiny an increase in total PTO revenues could be identified. Additionally, we observe a large discrepancy between the progressions of investment curves and revenue curves. Investment progression is much more volatile than revenue progression. While for the UK total revenue is in line with the evolution of investment, only little conformity could be found for the other countries. In many EU 15 countries telecommunication markets were liberalized in 1998.[11] As figure

[9]Source of Data: OECD

[10]A conservative estimate by the European Commission in 2005 comes to the result that telecommunications drive about 25 percent of GDP growth and about 40 percent of productivity growth (EuropeanCommission (2005)).

[11]An overview over the most important EU directives, the steps to liberalization and the first steps to privatization are illustrated in figure 5 in the appendix.

Figure 2: Revenue and Investment of PTO[12]



2, shows this intervention is reflected by a decrease in investment levels in close to all European countries and has affected the average investment function as well.

3.3 New Telecommunication Services and other Industries

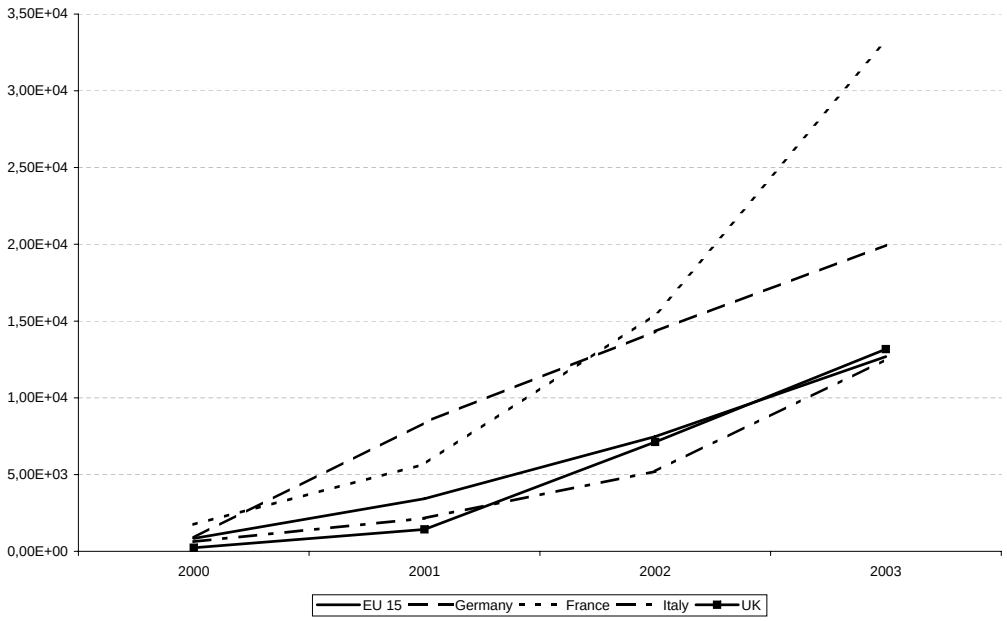
Waverman and Roeller (2001) argue that network providers can hardly internalize the total rent of infrastructure. Not only providers of telecommunication services gain from quality "upgrades".[13] Additionally, internet service providers (ISPs), e.g. owners of search engines or websites, also gain from infrastructural quality or quantity increases, because they can reach a larger share of customers. But they do not, or only partially, pay infrastructure providers for reducing congestion what – as Waverman and Roeller argue – results in externalities.

[12]Source of Data: ITU

[13]In what follows I use the term *quantity* in the infrastructure context to describe the availability of infrastructure. Therefore, increasing infrastructure quantity corresponds to a roll-out of infrastructure. In contrast, the term *quality* covers the capacity of installed lines. If a provider upgrades his infrastructure this could either mean installing new parallel lines to his own existing lines or in general installing equipment which allows for higher transmission rates.

Beside these new economy, traditional firms also use the internet as a communication platform to advertise their products or to communicate with providers of preliminary products. Consequently, completely new markets, so called e-markets, have been installed where regional barriers display only little restrictions to market participants. Since the beginning of internet service provision two effects are observable: Firstly, the

Figure 3: Broadband Availability per Population Density[14]

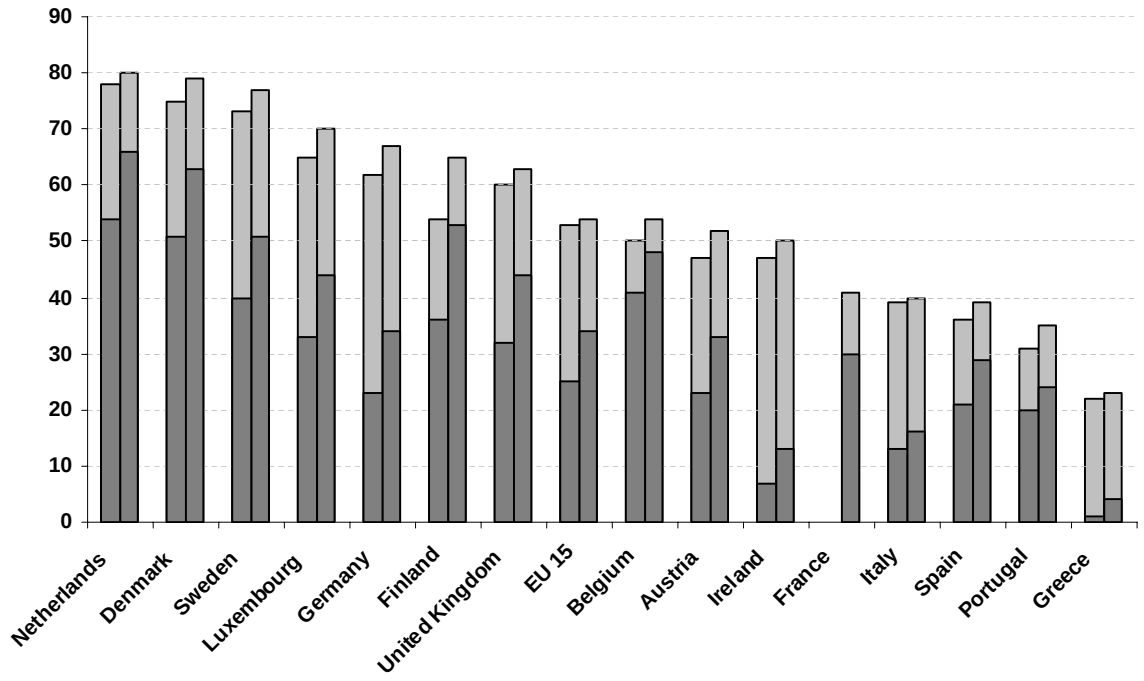


capacity of fixed lines (and latterly of mobile lines) is continuously increasing. Figure 3 illustrates the development of broadband roll-out between 2000 and 2003. From the underlying data we know that in countries with a high population density, i.e. a high population per area ratio, broadband could be made available to a larger share of population more easily.[15] Secondly, the number and the quality of e-services are both

[14]Sources of Data: ITU, OECD; values underlying the curves are calculated as follows: $\frac{(population_t/area)}{broadband_t}$, Table 5 in the appendix shows the change of internet availability, population density and the share of urban population between 1990 and 2004 for the EU 15 countries.

[15]At a first glance, France and Spain are two exemptions from this observation. Taking into account that the indicator compares a country's total population with its total area, this measure underestimates the concentration of populations in large countries. About 11% of the Spanish population are concentrated in Madrid and Barcelona, while more than 25% of the French population are concentrated around Paris and Marseille. Therefore, an indicator using urban population per area could lead to more precise results.

Figure 4: Share of Households with Internet Access[16]



increasing at an accelerating speed.
It is unclear whether the wish for more e-services at higher quality causes the roll-out of broadband or whether the availability of higher-capacity broadband triggers the supply of higher-quality services. As the OECD Communications Outlook 2007 shows, the number of hosts has strongly increased during the last 10 years. With more information offered via the common infrastructure, the capacity of this infrastructure has to be adjusted to the increasing data volume. Telecommunication operators try to handle the discrepancy between increasing data provision and capacity restrictions by offering special services to specific demand groups. In doing so, they try to internalize the problem of capacity restrictions for high capacity demanders.
Higher data transmission is not only a challenge with regard to the firm level but also arises in consumer context. As private demanders become more skilled in e-services they also ask for higher service quality thus increasing their demand for infrastructure of higher quality. Figure 4 illustrates the share of households with internet access in total and with internet access via broadband in 2005 and 2006. At a first glance both

[16]Source of Data: Eurostat, share of households with access to the internet and with broadband access in 2005 and 2006

the share of total internet subscribers and the share of broadband subscribers increase over time. At a second glance we can observe that access via broadband increases even faster than total internet access in nearly all EU 15 countries. At least some households upgrade the capacity of their terminal equipment and thus ask for higher mainline capacity.
Summarizing the main aspects of this discussion, we observe an ongoing increase in quality and quantity expansions of telecommunication infrastructure since the beginning of the 1990s.[17] The availability of "better" infrastructure has increased both service quality and quantity. Firms use the internet to increase their range of potential demanders at a lower cost than otherwise would be possible whereas households get more information for free.
Additionally, as the internet has become available to an increasing share of the population new services have been implemented which previously had no platform. Thus the roll-out of telecommunication infrastructure during the 1990s has not only improved telephony services but also enabled the existence of completely new markets which are highly sensitive to technological and to institutional modifications of the underlying infrastructure.

4 Hypotheses

Liberalization and Investment in Infrastructure
In economics on R&D at least three influences of competition on innovation are identified. All of them could easily be transferred to infrastructure investments after a regulatory shock as Friederiszick and Roeller (2007), for example, explain.
The *Schumpeterian Effect* is the most popular effect mentioned in innovation literature. An increasing number of competitors makes R&D efforts less affordable. As more competitors invest in R&D the individually expected returns will be reduced. This is not because the individual conditional probability of a positive outcome has changed but because as more competitors innovate in a market with close substitutes, there is a higher common probability that one competitor will succeed shortly after another, making the first innovation worthless.[18] Thus, the expected time for "harvesting" after successful research efforts is reduced. Consequently, as the number of competitors increases, all of whom want to gain from investments in product improvements, the individually expected returns will reduce. Adopting these results to a market with a common underlying infrastructure and very close substitutes in services, a network provider who simultaneously offers infrastructure and services will reduce infrastructure investments after liberalization in the expectance of reduced service outcome. Following the Schumpeterian idea we should expect a reduction in infrastructure investment after the liberalization.

[17] The table in appendix B displays a significant increase of mainlines which corresponds to an increased availability of telecommunication infrastructure to both firms and households. Additional data of the International Telecommunication Union (ITU), which is not presented here, shows only little changes in households' share of total mainlines between 1990 and 2004.
[18] so called "creative destruction"

The *Escape Effect* is the direct complement to the Schumpeterian Effect. Aghion et al. (2005), for example, argue that (at least additional to the Schumpeterian Effect) in markets with close substitutes higher investments in innovations should be identified. Both former competitors and new entrants know of each others' investments ex ante. Former competitors try to increase the access barrier for potential entrants by increasing their investments in R&D, thus signalling that being successful in the long-run is very costly. Additionally, higher investments in R&D are related to expectations of more radical innovations and – if successful – an increase of the gap between standard products and the new product. Entrants are aware of the incumbents' behavior. They know of the high investments necessary to enter the market. Relating the Escape Effect to telecommunications, we should find higher investments in infrastructure after the liberalization. Former incumbents and infrastructure operators who have entered the market very early increase investments both for signalling reasons and to increase service quality, thus making services more attractive for customers.
Following the argumentation of Aghion et al., Friederiszick and Roeller (2007) argue that both the Schumpeterian and the Escape Effect could also be found in investment behavior: Relating radical governmental intervention and infrastructure investment, an inverted-U shaped relationship should be identified as well. Shortly after the liberalization, former infrastructure incumbents increase their investments in network quality and quantity. They thus try to prevent new entrants from accessing the market by reducing the return on additional infrastructure investments (the Escape Effect). But – in particular with quantity investments – sooner or later a saturation point will be reached. Because over-investments decrease discounted marginal returns on investment in the long run, decreasing investments should be identified after this saturation point. This exactly corresponds to the Schumpeterian Effect.
In line with Dixit's hypothesis (Dixit (1980)) incumbents behave strategically, i.e. they not only do anticipate the behavior of new entrants and try to exacerbate their entry but they also know of the imminent liberalization and thus adjust their investments before the new entry actually takes place. Friederiszick and Roeller argue that regulation should not be taken as an exogenous variable per se in dynamic investment models. In particular in econometric analyses, one should use a model specification which takes into account strategic behavior on the part of network providers. Following this argumentation, incumbents internalize governmental intervention in investment decisions. We call this effect, which could be both positive or negative, *Internalization Effect*.

Privatization and Investments
Following the argumentation of the 1980s privatization results in a change of telecommunication providers' interests. Before privatization telecommunication providers are interested in covering the whole population at a common, high level of quality. After privatization network operators are only interested in increasing profits. Consequently, they alter investments in infrastructure to a level where they maximize individual revenue. Therefore, ambiguous effects should be expected: While investments are strongly increased in densely populated areas to increase network quality, investments in rural areas should be decreased. Taking privatization as the only driving force of investments, it

is unclear whether it increases or decreases total investments. In his analysis of African and Latin American telecommunication markets, Wallsten (2001) finds no significant influence of privatization on mainlines, thus, underlining this lack of clarity.
On the other hand, taking into account access by new infrastructure providers as well, the former monopolist now has to behave competitively (as do the new entrants). As a result they will offer network provision where they expect the highest return on investment. While the former monopolist still keeps the infrastructure in less densely populated areas, new network providers focus on urban regions and run into competition with all other providers in these areas. Consequently, in particular in densely populated regions the competitive pressure forces infrastructure providers to invest. This leads to over-investments compared to the monopolistic outcome. In fact, Wallsten finds a positive impact of the interaction of privatization and regulation on mainlines.

Upstream Cross-Market Spill-overs in Telecommunications
With the growing importance of e-services, telecommunication equipment itself is increasingly being reduced to a platform for new services. Changes in technology have led to new transmission systems where standard infrastructure is still in operation. These technological upgrades allow for higher quality in services offered using new transmission technology and, additionally, enable the implementation of totally new services (e.g. Multimedia Messaging).
Telecommunication service providers are therefore highly interested in infrastructure quality and quantity. On the one hand if infrastructure is available only at low qualitative level services cannot be offered or could be offered offered only with lower quality. In contrast to services on other platforms third degree price discrimination with regard to one telecommunication service is impossible.[19,20] If the underlying infrastructure is strongly congested, i.e. if the line is of low quality, transmission of large data packages is impossible.
On the other hand, if high quality infrastructure is available only to a small share of the population, the demand for high-quality services is very low, in particular taking into account network effects. Therefore, service providers demand for a qualitatively high infrastructure which covers a large share of the population.
In contrast to service providers, demanders for telecommunication services are only interested in service quality. Under the Universal Directive, telecommunication services should be available for all citizens of the EU. A difference arises between customers who have a choice between different levels of service quality and customers who are bound by their infrastructure quality. Customers who have access to telecommunication infrastructure of desired quality at the given access price are not interested in additional quality at a higher access price. In contrast customers with a high willingness to pay for infrastructure quality wish to have access to a higher network capacity.

[19] In contrast, e.g. you can travel first or second class on every railroad track.
[20] Even third degree price discrimination with bundle offers is only possible on higher-quality lines.

5 Data and Data Modifications

Data Sources
The data for the econometric analysis were primarily taken from the following sources: ITU World Telecommunications Indicator 2006, Eurostat and SourceOECD. Data from the ITU are provided on a yearly basis and include information on telecommunications revenues and investments. Furthermore, the database offers information on demand behavior like the share of mainlines kept by households, different pricing system information or different modes of telecommunication equipment used. Due to national differences in data collection the information offered in this database are mostly difficult to use in a panel data analysis or have to be complemented. I therefore concentrated as far as possible on variables which are completely available.
Additional data was taken from Eurostat. The database offers structural information and comprehensive data on ICT and telecommunications. These additional data were used to complement and extend the ITU database. Unfortunately, drawbacks exist with regard to the collection time. The majority of information on mobile telephony and internet usage was not collected until after 1997 or 2002. Thus, this information cannot be used for a long-run panel analysis.
Further structural information on countries was taken from SourceOECD while information on liberalization, market access and privatization was collected from different sources.

Data Modifications
In what follows I concentrate on two of the most important governmental interventions in telecommunication markets. On the one hand, I use data on the mobile phone market "liberalization" and on the other hand information on the liberalization of fixed line infrastructure and voice telephony. I do not focus on the point in time when – by jurisdiction – entrance on a particular market was allowed, but rather on when the first competitor entered the market. This difference is less important in the case of fixed infrastructure access where many firms could prepare their market entrance in advance of the date of liberalization.
The difference is much more important when considering the mobile phone market. In contrast to fixed phone markets, new mobile phone entrants had to purchase by auction a license for operating on a predetermined frequency. As a consequence in a two-step procedure potential entrants first bid for the licences and if they prevailed they invested in transmission equipment. In fact, many competitors entered the mobile telephony markets one year or more after they were allowed to do so. To control for market opening in fixed and mobile services I use dummies which switch from 0 to 1 when more than one operators are active.
I have constructed a dummy for privatization similar to that used for liberalization. This dummy takes the value 0 when the firm is completely under governmental control and 1 otherwise.
Figure 5 in the appendix summarizes the data used for fixed and mobile infrastructure access and privatization. Additional variables used in the estimations are the number of

personal computers, per capita fixed service revenue discounted to 1995 using the Consumer Price Index 1995 (CPI95), growth of discounted GDP, growth in discounted Gross Fixed Capital Formation (GFCF) and population per area. The dependent variable is total per capita infrastructure investments. These variables had to be adjusted both to make things comparable and to correct for causality. Variables used in the estimations are Granger-causality-tested to guarantee for unidirectional effects. State-Variables are used in log-form.[21]
Telecommunication investments strongly depend on country size and year specific influences. Assuming a similar AR(1) process for all countries deters information available on country level. Controlling separately for countries and for years ignores effects stemming from their interaction. For example one-year single-country shocks cannot be considered by two independent vectors. I therefore use a vector which includes country-year interaction dummies.[22]

Econometric Model
Infrastructure investments are long run investments which are *de facto* irreversible. Therefore, the decision about when to invest and how much to invest is of crucial interest for the decision makers. Because of the strategic outcome of investments they take into account multi-period budget constraints. Consequently, the influencing parameters on investment decisions in period $t-1$ strongly affect the investment decisions in period t. This endogeneity has to be taken into account in the estimation. The following equation covers these strategic intertemporal effects.

$$\begin{aligned} log\frac{totalinvestments_{it}}{population_{it}} = & \, lib'_{i,t-1}\,\beta_{lib} + priv'_{i,t-1}\,\beta_{priv} + \beta_{pc}\,log(\#PCs_{i,t-2}) \\ & + \beta_{rev}\,log\frac{fixrevenue_{i,t-1}}{population_{i,t-1}} + \beta_{dense}\,log(\frac{population_{i,t-1}}{area_i}) \\ & + growth'_{i,t-1}\,\beta_{growth} + \beta_{inv} log(\frac{totalinvestments_{i,t-1}}{population_{i,t-1}}) \\ & + country'_{i,t-1}\beta_{cy} + \gamma_i + \epsilon_{i,t} \end{aligned}$$

Subscripts i,t correspond to country i in period t. An overview over the variables used in the model is given in tables 2 and 3 in appendix B for 1990 and 2004.
$\frac{totalinvestments_{i,t}}{population_{i,t}}$ corresponds to total per capita investments in telecommunication infrastructure. The right hand side variables are lagged to avoid causality problems.
$lib_{i,t-1}$ is a vector of dummies which take the value 1 when more than one operator is

[21] A more popular way of correcting financial data is dividing by GDP or a GDP deflator. As discussed in section 3.2 telecommunication is a driving force of GDP. Table 5 in the appendix not only shows cross-country differences but also shows strong differences in the development over time. Consequently, correcting with GDP to cover country effects distorts results because independent variables influence both the telecommunication variables and GDP. Thus, it is unclear what would be the effect covered by the estimation coefficients. I therefore refrain from this approach and instead try to cover size effects by correcting with total population. Alternatively one could use employees. But then additional effects like age or sex differences in the work-force across countries might have deterring influences.

[22] In contrast to Wallsten (2001), estimations which are not presented here using year dummies and country dummies or assuming a common linear time trend lead to insignificant estimation results.

active in the market under scrutiny (i.e. more than one mobile phone operator or more than one fixed service operator). Additionally, to examine internalization effects of incumbent operators I have included a dummy to control for pre-drawing which takes the value 1 for the year before the first new operator has entered.[23] $priv_{i,t-1}$ is a vector with a privatization dummy taking the value 1 after the first step, reducing direct governmental control over the former state-owned monopolist, has been taken. Furthermore, interaction terms of privatization and liberalization dummies are covered by this vector. $\#PCs_{i,t-2}$ is a variable covering the number of personal computers used. It is lagged two periods because there is a strong negative correlation in a shorter time span to total investments in telecommunication infrastructure, which would strongly deter the influence of the other parameters. $\#PCs$ is used as a proxy for internet penetration by service demanders. Unfortunately, adequate data on internet penetration is not available before 2000. Nevertheless, also the very recent OECD Communications Outlook 2007 shows in particular for the covered EU 15 countries a strong overlap of the number of personal computers and internet penetration. Taking into account that in the early days of privately used computers, these were only rarely connected and that the internet did not become affordable and attractive until after the development of the World Wide Web in 1989, the number of personal computers is the only variable available which covers the period of using the internet as more than a scientific network. Additionally, at least since the mid-1990s most personal computers in use are connected to the internet.
$\frac{fixrevenue_{i,t-1}}{population_{i,t-1}}$ corresponds to the per capita revenue for fixed line services.[24] $\frac{population_{i,t-1}}{area_i}$ is a measure of density covering total population per country area. Unfortunately, measures for urban population for the time period under consideration has large lags. Both the ITU database and SourceOECD offer data on urban population but both are quite different in construction and thus cannot be used to complement each other. $growth_{i,t-1}$ is a vector of the two variables for growth of discounted GDP and growth of discounted GFCF between $t-2$ and $t-1$.
For equation i,t the dummy representing country i and year t in the vector $country_{i,t}$ takes the value 1 whereas all other dummies are zero. This vector controls for all country year specific effects.
γ_i are the random effects which are independent and identically distributed (iid) across all countries. $\epsilon_{i,t}$ are the iid error terms. βs are the coefficients which are estimated.
The above model uses the dependent variable in year $t-1$ to explain the dependent variable in year t. This internalization is considered in the class of dynamic panel data estimators. In my analysis, I use the Arellano-Bond approach which belongs to the group General Method of Moments (GMM) estimators. The Arellano-Bond estimator uses the differences of the strictly exogenous variables and the lagged level of the dependent variable to explain the dependent variable. In contrast to the other covariates, in my specification the country-year dummies are strictly exogenous instruments which

[23] Additional lagged years could be neglected both by taking a closer look on figure 2 and in particular because of no significance in additional estimations not presented here.

[24] Using instead total revenues or additionally mobile service revenues for all telecommunication services has led to causality and consequently distorts the influence of the other exogenous parameters.

are not differentiated in the estimation.

6 Estimation Results and Discussion

Table 1: Total Investments in Telecommunication Infrastructure

	log (per capita investments)		
	(1)	(2)	(3)
access fixed lines	0.170* (0.095)	0.164* (0.093)	0.196** (0.092)
access mobile infrastr.	−0.078 (0.061)	−0.079 (0.061)	−0.091* (0.054)
internalization (1 year)		−0.100 (0.104)	
access fixed lines (big 4)			−0.138 (0.116)
privatization	0.037 (0.084)	0.038 (0.080)	0.029 (0.079)
priv. x access fixed	−0.187** (0.098)	−0.221** (0.095)	−0.162 (0.111)
priv. x access mob.	0.139* (0.081)	0.164** (0.073)	0.121 (0.092)
log (# PCs)	−0.070 (0.137)	−0.069 (0.135)	−0.050 (0.129)
log (per cap. fixed serv. rev.)	0.257***(0.054)	0.241***(0.052)	0.271***(0.058)
log (pop. density)	−0.725 (1.192)	−0.756 (1.238)	−1.333 (1.437)
GDP growth	0.415** (0.208)	0.403* (0.212)	0.394* (0.202)
GFCF growth	0.062 (0.048)	0.054 (0.041)	0.064 (0.049)
log (per capita investments (t-1))	0.603***(0.081)	0.604***(0.080)	0.573***(0.073)
constant	0.021 (0.024)	0.023 (0.024)	0.024 (0.021)
Wald $\chi^2(df)$ Test	10,388.97	11,1079.49	11,895.73
AB Test (1^{st} order autocorr.)	***	***	***
# observations	193	193	193

Notes: ***, ** and * correspond to the 1 per cent , 5 per cent and 10 per cent significance levels. Standard errors are presented in brackets.

Table 1 displays the estimation results of the econometric model described in section 5. Column 1 presents the results of the base estimation. The second estimation includes a dummy to control for the four largest countries – France, Germany, Italy and the U.K.. The last column differs from the first by controlling for the pre-drawing assumption. Country-year interaction terms are not presented.[25]

[25]For the estimations in table 5 in appendix C a similar model is assumed. In contrast to the estimations

The Impact of Liberalization and Privatization on Investments in Infrastructure
While a significant positive effect of market opening on infrastructure access and a even stronger negative effect from mobile competition can be found, privatization alone has no significant impact on investment. Taking into account the discussion above, competition on fixed infrastructure markets, on a first glance, has led to an increase in investments. This would fit with a situation in which the Escape Effect outweighs the Schumpeterian Effect. In contrast, competition in mobile telephony has decreased investments, but is of significance only in specification 3.
This direct interpretation is probably insufficient. Given the construction of the dummies, access to the fixed infrastructure markets in close to all countries was allowed after the first step to privatization had been taken. Therefore, the total effect is the sum of the access to fixed lines coefficient and the interaction with privatization coefficient. Thus, the total effect of allowing fixed line competition is negative. Similar to Wallsten's findings, the sequence of first privatization and then liberalization of the former monopolistic infrastructure providers negatively affects investments in fixed lines. Wallsten explains these findings with a change in the incumbents' interests. Whereas under more governmental control former monopolists performed a social duty by offering adequate services for all citizens, after the first steps to privatization, the social character was reduced. With the entrance of competitors the incumbent operators' business volume was reduced, with subsequent negative effects on the budget of investments.
As Eurostat data show, in 2004 in almost all EU 15 countries the former monopolists still held the dominant position in fixed line services. While new operators are profit maximizers the former monopolists are obliged to offer universal services as well. Therefore, with a *ceteris paribus* reduced business volume, new investments by the former monopolists had to be reduced and are mainly concentrated in competitive areas. Taking into account the direct effect of liberalization and the interaction effect with privatization, competition on the fixed infrastructure markets has reduced investments. This supports the Friederiszick and Roeller (2007) hypothesis that in the long run the Schumpeterian Effect outweighs the Escape Effect.
Duso and Roeller (2003) and Friederiszick and Roeller (2007) additionally mention a potential Internalization Effect. Following Laffont and Tirole (1990) a strategic increase in investments before liberalization corresponds to constructing an access barrier and thus deters potential competitors from entering the market. Alternatively, decreasing investment corresponds to the expectation that competitors at the service level will reduce one's own return on infrastructure investments.
From our findings in figure 2 we should have expected a negative Internalization Effect during the year before the fixed line markets were liberalized. The internalization dummy in estimation 2 indeed has a negative sign but is of no significance. Even controlling for the big 4 countries or for additional years of strategic behavior is of no significance. Thus, for the EU 15 countries, we cannot confirm the hypothesis of internalization in

displayed here I took country specific linear time trends to cover differences across countries and time. A short comparison between the estimation results displayed here and those in the appendix can be found on page 28.

the liberalization context.[26]
In contrast to opening fixed line infrastructure and taking into account privatization, the total mobile liberalization effect is positive. This finding is in line with the market opening procedures described in section 5. Firms competing for licenses to offer mobile infrastructure and services know in advance how much they have to invest to cover an adequate share of the population. Furthermore, mobile services are not covered by the Universal Service Obligation. So, new competitors could first concentrate on urban areas. The higher and – more importantly – certain returns in contrast to fixed infrastructure services in line with the low number of competitors enabled high investments shortly after the licenses were granted.
Another difference to fixed infrastructure stems from the technological change which took place close to the opening of mobile phone markets. In contrast to former analogue mobile technology, GSM (Global System for Mobile Communications), which was established in 1992, facilitates the transmission procedure and allows for larger data packages by means of digital transmission. Infrastructure which was installed by the former monopolist had to be upgraded or replaced by new technology. Consequently, the former monopolist gained only little (if at all) from its first mover position in mobile phone markets and in fact was faced with competition from only shortly after the early beginnings of GSM technology.[27]
In order to cover a large share of population, both the former monopolists and their competitors had to invest intensively in building new transmission capacities. Therefore, both the new technology and competitive pressure forced mobile communication network operators to install an adequate infrastructure. Because network providers were selected through a procedure of license granting, investments are closely related to market access of new providers.

Cross-Market Spill-overs from Telecommunication Services to Infrastructure Investments
As expected we can identify a highly significant strong impact of service revenues on infrastructure investments. In some cases, services are provided by integrated firms which offer also infrastructure access. Therefore, these firms are interested in high infrastructure quality because they gain twice from service provision and from infrastructure provision.
Non-integrated service providers are also interested in a high level of infrastructure capacity. They try to set their range of services apart from the services offered by their competitors by concentrating on a low number of demand groups, on special services or service bundles, as well as by price competition. In particular, the last two strategies require the new entrants to have cost advantages over the former monopolists in ser-

[26] It is probably necessary to use more detailed information to analyze the strategic behavior of the former monopolists than only year control variables. This drawback of the current study will be focussed on future work.

[27] Differences stemming from country specific implementation of the digital transmission technology are covered in the country-year dummies and therefore do not distort the coefficient of the entrance-to-mobile-service dummy.

vices.[28]
One alternative for differentiation among competitors is based on special requests of demanders. With telecommunications the speciality mainly results from an increasing demand for the integration of telecommunication into established processes. The integration of formerly separated data exchange systems into telecommunication systems requires an extension of service quality and results additionally in an enlargement of the number of services. Service providers therefore are highly interested in higher infrastructure capacity and availability.
Telecommunication services are mostly network goods. That means it is insufficient if only one partner has access to high capacity telecommunication infrastructure whereas the other cannot use the same service simultaneously. As a result, service providers offering a particular service for a specific group of demanders are highly interested in all participants in this group being connected to an infrastructure of sufficient quality. This strategy of concentrating on special services is one way to internalize externalities from telecommunication services.
Alternatively, integrated infrastructure and service providers offer special services to firms with very high data transmission rates. Firms like Colt[29] only address medium-sized and large scale enterprizes. In doing so, these telecommunication companies could at least partially internalize externalities from their customers' internet presence both by offering services and networks at an adequate capacity. Simultaneously, they avoid over-capacities by tailoring infrastructure to the requirements of their customers.
We find a significant high impact of service revenues on investments but cannot identify significance resulting from a service demand pull. Because of the nature of the survey, I do not have more detailed data on the demand for telecommunication services covering the whole period from 1990 to 2004. Thus, most of the effect stemming from demand for quality is included in service revenue. Nevertheless, we find a highly significant impact of telecommunication service revenue on investments, also when controlling for year specific or trend effects and lagging the revenue variable. Taking into account the fact that special service offers at least partially cover the investments in capacities could be identified as an attempt to internalize externalities.

The estimation results show significant effects from mobile and from fixed service regulation on infrastructure investments. Similarly to Wallsten (2001) and to Wallsten (2002), we find that privatization itself has no impact on investments. But taking into account interaction terms with governmental intervention, we find evidence that monopolists and competitors adjust their investment behavior after the market opening at the service level.
The demand for telecommunication services itself depends on services which can only partially be internalized by telecommunication service providers in their price settings, as Duso and Roeller (2003), for example, explain. Figure 4 shows both an increase in

[28] Otherwise the monopolists continues Bertrand competition which was first triggered by the non-integrated firms.
[29] www.colt.net

internet demand and an even stronger increase in the demand for high infrastructure quality as well. Telecommunication infrastructure and internet access have no direct positive effects on demanders' utility or profits. But the access to the infrastructure is a vehicle to reach special internet services, which influence the demanders' outcome. Therefore, increasing infrastructure quantity or quality indirectly affects total outcome. Taking into account uncertainty and incomplete knowledge makes regulation very difficult. The uncertainty about additional future interventions reduces the incentive to invest in infrastructure because expected future returns might be reduced. Telecommunication infrastructure and service providers try to cover this uncertainty by concentrating on special demand groups.

7 Conclusion and Further Research

The growing demand for telecommunication services and the comprehensive integration of telecommunication services into business processes characterize telecommunications as a key sector for other industries. Taking into account the increasing importance of telecommunications for GDP, as can be seen in the increasing telecommunication revenue per GDP-ratio and as is stated by public institutions, these spill-overs have crucial effects on welfare.

In the analysis in this paper I have taken a closer look on spill-overs between telecommunication service markets and infrastructure investments. Like in no other sector, telecommunications show strong linkages between the infrastructure and the service level. In the descriptive analysis, I therefore propose reasons why both infrastructure "upgrades" drive service innovations and services drive investments in infrastructure. While the first causality is straightforward for services requiring a special infrastructure, the second approach is more complex.

Services operating on a given infrastructure require a specific infrastructure capacity. Otherwise they cannot be offered or could be offered only at a lower quality. From the descriptive analysis we know that demanders do not only desire infrastructure availability but, additionally, are interested in this infrastructure being of high quality. As infrastructure itself does not increase demanders' profits or utility, the wish for more infrastructure capacity could only result from the demand for more and "better" services. Controlling for causality, we indeed identify a significant positive effect of increasing service level revenues on infrastructure investments.

Opening fixed line infrastructure has a significant negative impact on investments. Former monopolists still keep the largest share of infrastructure. But because they face competition on service markets, their revenues are reduced, strongly affecting the budget for investments. Incumbents have to act in the interest of their shareholders but are also obliged to offer infrastructure at an adequate level which causes conflicts of interest. In contrast, their competitors are "only" profit maximizers. They therefore concentrate investments on higher populated areas and offer additional services on incumbents' lines in less densely populated regions. Consequently, former monopolists are forced to accept

lower returns on investments than their cherry-picking competitors: At the wholesale level they have to offer capacities to competitors and simultaneously they face Bertrand-competition of new entrants, in particular in densely populated regions.
In contrast, investments in mobile infrastructure were strongly increased by market opening. Access to mobile phone markets was granted via licenses. As opposed to fixed line telephony, the former monopolists were not forced to open their networks to competitive services. Thus, new entrants had to invest in their own infrastructure. Because access to mobile service markets was only possible by means of a license, investments in parallel equipment were not implemented before the license was granted.
Thus in total, we find two ambiguous effects of infrastructure openings on investments which are at least partially driven by different ways of granting access. In telecommunications, governmental interventions have a strong long-run effect on the sector itself but additionally on the outcome in other industries. Such interventions could thus easily deter competition at country level.

This study is only a preliminary analysis of spill-overs in telecommunication markets. In future work the econometric analysis of this paper will be complemented by examining the effects of interventions in telecommunication markets on other industries.
Additionally, a more complex consideration of the strategic behavior of infrastructure and service providers on governmental interventions will be accomplished to further deepen the analysis of the Endogeniety Effect as stated by Duso and Roeller (2003) and Friederiszick and Roeller (2007).
Because of the very preliminary version of this paper, please do not quote the results.

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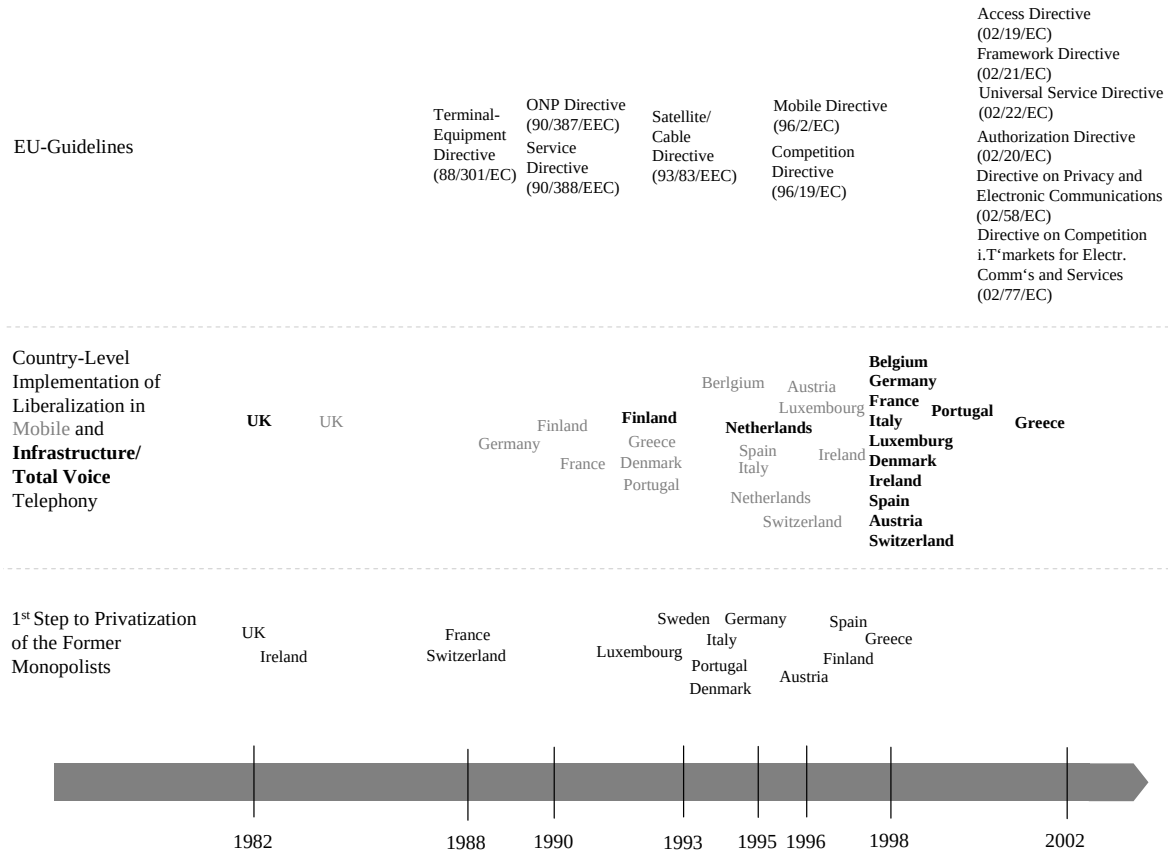
Appendix

A Market Access and Privatization

Figure 5: Steps to Competition on EU 15 Telecommunication Markets



B Descriptive Statistics and Additional Figures comparing 1990 and 2004

Table 2: Descriptive Statistics 1990

	Mean	Std. Dev.	Minimum	Maximum
log (per capita investments)	4.483	0.532	2.965	5.052
access fixed lines	0.133	0.352	0	1
access mobile infrastr.	0.133	0.352	0	1
privatization	0.333	0.488	0	1
priv. x access fixed	0.067	0.258	0	1
priv. x access mob.	0.067	0.258	0	1
log (# PCs)	13.625	1.297	11.151	15.687
log (per cap. fixed serv. rev.)	0.721	0.513	-0.593	1.397
log (pop. density)	4.638	0.921	2.693	5.886
GDP growth (1989/1990)	0.096	0.079	-0.059	0.250
GFCF growth (1990/1991)	0.300	0.070	0.196	0.423

Notes: Financial data are discounted using CPI95.

Table 3: Descriptive Statistics 2004

	Mean	Std. Dev.	Minimum	Maximum
log (per capita investments)	5.261	0.512	4.531	6.498
access fixed lines	1	0	0	1
access mobile infrastr.	1	0	0	1
privatization	0.933	0.258	0	1
priv. x access fixed	0.933	0.258	0	1
priv. x access mob.	0.933	0.258	0	1
log (# PCs)	15.379	1.368	12.543	17.504
log (per cap. fixed serv. rev.)	1.333	0.413	0.777	2.189
log (pop. density)	4.714	0.925	2.736	5.968
GDP growth (2003/2004)	0.106	0.035	0.073	0.183
GFCF growth (2003/2004)	0.166	0.044	0.056	0.253

Notes: Financial data are discounted using CPI95.

Table 4: Main Figures 1990 and 2004

	Mainlines in 10^3		Total Inv.'s in Infrastr. in 10^6 Euro		per capita GDP		Contrib. of Telecomm. to GDP		av. ML Growth	av. per cap. GDP Growth
	1990	2004	1990	2004	1990	2004	1990	2004		
Austria	3223	3791	1200	1126^e	17713.29	41308.72	1.77	2.31	1.17	6.23
Belgium	3913	4801	739.4	2053	17557.94	39920.16	1.37	2.05	1.47	6.04
Denmark	2911	3492	477	1160	23561.90	54703.38	1.74	2.61	1.31	6.20
Finland	2670	2368	696.5	919^e	24409.76	40260.74	1.64	2.97	-0.85	3.64
France	28085	33870	4302	8059^e	19220.60	38719.93	1.56	2.20	1.35	5.13
Germany	31887	54574	10220	7959	17833.20	37454.09	1.84	3.02	3.91	5.44
Greece	3949	6349	197.1	1942	4261.81	26850.96	1.56	4.73	3.45	14.05
Ireland	983	2015	256.8	459.2^e	11333.14	46994.81	2.64	3.51	5.26	10.69
Italy	22350	25957	6468	13690^e	14967.05	35862.07	1.32	3.10	1.07	6.44
Luxembourg	184	245	51.1	150.8^e	24512.24	81481.48	1.81	1.67	2.08	8.96
Netherlands	6940	7861	1297	6571	16587.52	46342.52	1.87		0.89	7.61
Portugal	2379	4238	504	1632	4975.53	20609.24	2.01	5.44	4.21	10.68
Spain	12603	17934	5502	7431	9577.02	30788.46	1.70	4.45	2.55	8.70
Sweden	5849	6447	866.1	2015^e	22582.74	42501.76	2.10	2.90	0.70	4.62
United Kingdom	25368	33700	4167	21910^e	14593.47		2.37		2.05	

e = estimated by harmonized extrapolation and interpolation, all financial data discounted using CPI95

C Additional Estimations Assuming country specific linear trends

Table 5: Total Investments in Telecommunication Infrastructure

	log (per capita investments)		
	(1)	(2)	(3)
access fixed lines	0.220*** (0.075)	0.220*** (0.074)	0.268*** (0.097)
access mobile infrastr.	0.005 (0.070)	0.003 (0.070)	−0.000 (0.067)
internalization (1 year)		−0.116 (0.116)	
access fixed lines (big 4)			−0.129 (0.129)
privatization	0.046 (0.096)	0.047 (0.096)	0.037 (0.101)
priv. x access fixed	−0.185 (0.113)	−0.238** (0.113)	−0.180 (0.110)
priv. x access mob.	0.169 (0.103)	0.203* (0.112)	0.163 (0.113)
log (# PCs)	−0.271** (0.125)	−0.269** (0.125)	−0.219 (0.154)
log (per cap. fixed serv. rev.)	0.279*** (0.096)	0.257*** (0.099)	0.302*** (0.102)
log (pop. density)	−1.477 (1.105)	−1.495 (1.133)	−1.723 (1.200)
GDP growth	0.432** (0.211)	0.412* (0.219)	0.432** (0.211)
GFCF growth	0.039 (0.044)	0.029 (0.037)	0.039 (0.042)
log (per capita investments (t-1))	0.633*** (0.084)	0.633*** (0.084)	0.599*** (0.080)
constant	0.040* (0.023)	0.042* (0.024)	0.035 (0.026)
Wald $\chi^2(df)$ Test	10,407.99	11,477.79	11,292.08
AB Test (1^{st} order autocorr.)	***	***	***
# observations	193	193	193

Notes: ***, ** and * correspond to the 1 per cent , 5 per cent and 10 per cent significance levels. Standard errors are presented in brackets.

For the estimation results displayed in table 5 I have used approximately the same model specification as in the estimations in section 6. The only difference stems from the assumption of a country specific linear time trend. Results differ only slightly from those displayed in table 1. Standard errors have increased. This is a result of the fact that in the estimations in table 1 I have a control variable for each country and each year. In contrast, in the estimations in table 5 I control for countries but assume the same time trend for all countries. Thus, I ignore country-year specific departures from the common trend.