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A Definition for Infrastructure - Characteristics and Their Impact on Firms Active in Infrastructure

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Abstract

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by Eva Kasper

The key question of this thesis is whether private investments in infrastructure are profitable. Infrastructure plays a critical part of a country's development. This thesis develops a definition of economic infrastructure. The definition is based on the assumption that economic infrastructure relies on physical networks. Thus, network theory can be applied. Several parts of physical networks show economies of scale and scope and have long construction lags. Along with the lack of alternative uses for infrastructure assets these impose monopolistic structures. This definition of infrastructure is then applied to different sectors, so that the characteristics of the various subsectors and levels can be assessed.

Investors who own and operate infrastructure benefit from monopolistic structures as they can exploit them and gain excess profits. Simultaneously, these monopolistic structures reduce social welfare and thus are often regulated or owned and operated by governments. The thesis points out that private ownership and regulation might be the superior structure, but regulation is necessary especially when cost cutting decreases quality.

The assessment of the characteristics of different infrastructure sectors is used to identify publicly listed firms that own and operate economic infrastructure and to analyze their performance. This panel set of data creates the opportunity to empirically analyze whether the performance of firms active in infrastructure is correlated to the identified variables of theoretical definition, namely differences of sectors, of network structures, of vertical integration and market power and regulation. The empirical analyses highlight that firms active in various sectors show different current performance (returns on assets) and future expected performance (Tobin's Q). The performance is influenced by a range of variables, including firm-specific variables,

but also country-specific variables and regulatory indicators. In the full set of firms population growth and the reduction of regulation have positive effects on current performance. In contrast, firms owning infrastructure profit from stricter regulation while vertically integrated firms profit from reduced regulation. Firms active in undirected networks seem to profit from direct network effects, as population growth and GDP per capita influence performance positively.

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Abbreviations

ATM	Automated teller machine, cash machine
AT&T	North American telecommunication enterprise
BOO	Build-own-operate
BOOT	Build-operate-own-transfer
BOT	Build-operate-transfer
BRICS	Brasil, Russia, India, China and South Africa
BT	Build-transfer
CEFS	Center for Entrepreneurial and Financial Studies
CIA	Central Intelligence Agency
CO_2	Carbon dioxide
DBFO	Design-build-finance-operate
DBO	Design-build-operate
EBIT	Earnings before interest and taxes
EPEC	European PPP Expertise Center
EQ	Equity
ETCR	OECD indicators of regulation in energy, transport and communications
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas
GSIC	Global Standard Industrial Classification
LTE	Long term evolution, wireless telecommunication standard for high speed data
MNE	Multinational enterprise
multis	Firms active in several infrastructure sectors

OECD	Organisation for Economic Co-operation and Development
OM	Operating-maintenance
OT	Operate-transfer
PFI	Private finance initiative
PLAUT	Indicator for Regulation in Telecommunication
PPP	Public private partnership
QWERTY	Systematic of keys on the keyboard
ROA	Return on assets
SIC	Standard Industrial Classification
st. dev.	Standard deviation
TÜV	Technical inspection agency (Technischer Überwachungs Verein - German institution to regularly inspect products and guarantee technical security of products)
TV	Television
TQ	Tobin's Q
UN	United Nations
US	United States
US$	US Dollar
VIF	Variance inflation factor
WAAC	Weighted cost of capital
Wi-Fi	Technology to exchange data without wire
WWS	Wind, water, sun

Chapter 1

Introduction

The key question of this thesis is whether private investments in infrastructure are profitable. Infrastructure is one driver of economic development, enabling globalization (See e.g. Straub (2008), p. 7pp, Henckel, McKibbin (2010), p. 3pp). Despite this fact for years governments invest less in infrastructure so that private investors become important to fill the gap of constructing and maintaining infrastructure. This thesis develops a taxonomy for infrastructure and analyses whether the assumed relationships and properties display in the performance of infrastructure firms and the market's valuation of the firms' investments.

1.1 Relevance of Infrastructure

The most basic infrastructure, water supply, highlights the importance of infrastructure for any development: Access to drinking water is necessary for human life and a sufficient waste-water treatment extends life expectancy by reducing the risk of water-related infections. Clean sweet water enables the irrigation of plantations in arid areas or seasons and thus prevents malnutrition. Irrigated plantations yield higher outputs and show lower risks in failure than non-irrigated plantations. In basic subsistence economies these excess-outputs can be sold on markets; the earnings can be invested in different nutritional products or in health care, saved for bad times or used to send children to school. Access to clean water is essential for development and economic progress. Among the United Nations (UN) millennium development goals it is one cornerstone. In 2010, 89% of the world's population, about 6.1 billion people, had access to safe drinking water (several papers examine different parts of this topic, which can be seen as common knowledge. The information displayed here can be found in Gronewegen, Künneke, Anger (2009) or Clausen and Rothgang (2004)).

While water is the most basic aspect within the topic of infrastructure, other sectors are equally of high importance. Transportation enables trade between regions with different resources, production-foci and productive advantages[1]. Regions active in mining sell their yielded products to regions that cultivate food and vice versa. Historically, salt harvested in distant areas, was transported on so-called salt routes and allowed cities, located on these routes, to tax traders and travelers and thus became rich (see e.g. Freitag, (2004)). Ports importing goods, such as Lisbon in Portugal and Venice in Italy, prospered as the goods were sold and distributed on the European continent (see e.g. Lane (1966) for Venice). The shipping of goods from different continents was risky and expensive, and lead merchants in Italy to develop risk mitigating strategies and to introduce the first types of insurances (see e.g. Kohn (1999), p. 100pp). Since ancient times transport was important for the Mediterranean region as it facilitates communication and trade (Andrieu (2007)), a basis for development. Railways have been carrying passengers and goods since the 18th century; they were able to transport larger amounts at a faster speed than horses and carriages and thus created new opportunities for trade and travel. Transported goods could have been sold in areas with scarcity of this good for high prices.

Today transport is faster and seems less risky. Ships still transport huge amounts of goods between different parts of the world. Most of these goods are produced in emerging and developing countries, in huge plants with low wage costs, safety rules and ecological standards compared to developed countries. Planes can carry

[1] Newberry (2008), p. 18, for example states that the reduction of transport costs based on an existent transportation infrastructure creates new markets and fosters competition and innovation, thus leading to lower prices and higher productivity and thereby increasing living standards.

anything and anyone to any destination where planes can land and depart. Cars and trucks are the preferred means of transport when more individualized routes are requested. The decreased prices for public transport within densely populated areas additionally increase opportunities to sell and buy, but also to work and earn money (see e.g. Newberry (2008), p. 728).

The new types of transport are powered by energy. Energy is essential to keep the globalization running and to connect production and consumption in different parts of the world. Heating always was of importance in cold areas, as coldness weakens the human immunity system and thus heating increases the productivity of the work force. In contrast, in warm and humid areas, energy-powered air conditioning increases productivity (studies show a positive correlation between lower temperature and ventilation and better concentration of pupils (see e.g. Wargocki, Wayon (2007), p. 193pp)).

In addition, electricity enables telecommunication, the transfer of data between distanced places. Telecommunication allows orders to be exchanged in real-time between continents, problems within the operation process can be managed in time and input shortages can be solved with deliveries arriving with the next plane. Monitoring and improving outsourced production can often be handled via telephone, video-conferences and fast data transfer. Markets for different products on different continents are connected, arbitrage minimized and information problems mitigated. Telecommunication improves markets and reduces costs.

Accordingly infrastructure and investments are essential for economies. Studies, for example by Easterly and Levine ((1998), p. 121pp) find that an economic growth of 1 percent in one country increases the growth rate of the neighboring country by 0.4 to 0.7 percent. This observation is associated with spillover effects based on infrastructure investments (Henckel, McKibbin (2010)).

1.2 Approach of Research

Despite the importance of infrastructure, there are still gaps in theoretical and empirical research, so that currently no accepted definition for infrastructure exists. In consequence infrastructure lacks a theoretical foundation. Figure 1 shows the relationships of the different chapters and topics discussed in this thesis.

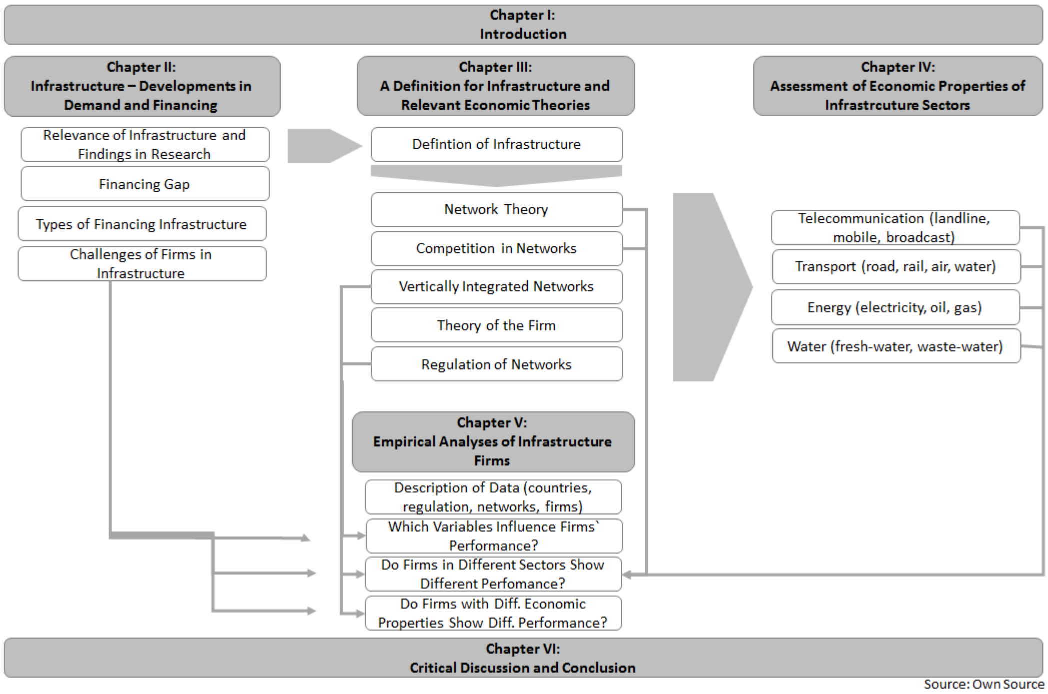


FIGURE 1: Overview of the Chapters

In chapter 2 the relevant literature on the importance of infrastructure for economic development is presented, and discussed within different applied sectors and topics. The review sharpens two insights. First, there exists no consensus on a definition of infrastructure. Second, infrastructure is of significant importance for economic development. The thesis than highlights the fact, that infrastructure faces immense investment necessities to meet the demand. The increasing importance of infrastructure on economic growth is fostered by consumers' demand requesting more and more reliable infrastructure. But in contrast, governments are facing increasingly tight budgets and are not able to meet the demand for infrastructure. Thus private investments are filling the financing gaps and start owning and operating infrastructure. Typical forms of private participation in infrastructure businesses are lined out in detail. For private investors performance of their investments is of greater relevance as it is to public investors in infrastructure. To be able to assess the performance two indicators are introduced: the return on assets (ROA) and the market's valuation of the firms investments, presented by Tobin's Q. These performance measurements should be influenced by the economic properties of infrastructure.

Therefore the third chapter of economic theory concentrates on the economic analysis of infrastructure, which leads to an economically based definition of infrastructure characteristics. It asks what infrastructure is. It is evident that "access to water", "access to energy", "transport" and "data transfer" (as in telecommunication) are only the services that use an existing infrastructure. These services can be summarized as infrastructure services. But they are not the infrastructure itself. When talking about infrastructure, the topics associated with are usually locational factors like transport, telecommunication, education, health services and cultural infrastructure, which display a wide variety of regional relevant factors. But so far there is no consensus what to understand and discuss when talking about infrastructure. So the first topic of this thesis is:

- How can infrastructure be defined and differentiated?

The definition of infrastructure leads to the discussion of several economic theories such as network theory, theory of competition, vertical integration, privatization and regulation. Based on the theory properties (different levels of ownership and vertical integration) of infrastructure and network types are assessed. So the second topic of the thesis is:

- Which properties and network types of infrastructure are relevant for firms' current and future performance?

The theoretical part highlights several properties such as network effects, economies of scale and scope and vertical integration, all closely related to questions of monopoly and oligopoly power. Thus regulation is highlighted as an important topic for investments in infrastructure. So the third topic focuses on regulation:

- Does regulation of infrastructure prevent monopoly power and thus decrease the performance of firms active in infrastructure?
- Does regulation affect firms differently based on the determined properties and network types?

In chapter 4 the definition of infrastructure, being physical networks, and its economic properties are applied to the different sectors identified to be in accordance with the definition. The development of the sectors and some highlights of its regulations are displayed. The description of the sectors introduces the next question:

- Exhibit the different sectors different investment opportunities?

The findings of the theory and the sectors are applied to a set of firms active in infrastructure as proposed in the definition. Based on this set the different hypotheses, summarized in the next paragraph are tested empirically in chapter 5. The findings and conclusions are summarized and discussed in chapter 6.

1.3 Hypotheses

Infrastructure investments promise long-term stable cash flows with low risks and seem to be an ideal complement to an existing portfolio. A new branch of research in this area treats these topics, but it is severely limited by the missing definition of infrastructure. Thus, based on the definition developed in chapter 3 and 4 of the thesis, hypotheses are developed to assess in the empirical part the performance of firms active in infrastructure.

- Do the specific characteristics (such as owning infrastructure or being completely vertically integrated) of infrastructure influence the performance of listed firms active in infrastructure and how does the market assess them?

- Do different sectors respond differently to firm-, country- and market-specific variables as well as to sector specific regulation?

- Do firms with characteristics specified in the theoretical part correspond differently to firm-, country- or market- specific variables as well as to sector-specific regulation?

More specific the hypotheses refer to the following assumptions.

- So called network effects increase the profitability of a network in relation with the number of consumers. This effect should be smaller for networks with a direction (e.g. a water network) than for a network with no direction (e.g. telecommunication).

- The theoretical definition affirms that some parts of the networks show monopolistic structures. A firm owning a monopolistic part of the network should show a better performance than firms owning competitive network parts.

- Another factor is vertical integration of firms, not only owning nodes and edges but also offering services to the consumers. Vertical integration, especially when parts are monopolistic, offers the firm the possibility to ask higher prices and prevent competition. Therefore performance should be better for vertically integrated firms.

- Monopolistic structures lead to high prices and low quality and quantity and thus is not in a countries interest, especially as infrastructure influences economic growth. Thus governments try to reduce the negative outcomes by different types of regulation. Regulation thus should reduce firms performance.

The results are relevant for different groups. Investors, owners and operators of infrastructure get an insight into how market structure, regulation, competition, network size and vertical integration influence firms' performance and how the capital market assesses the future performance of firms' assets. Equally should the results enable politicians and regulators to understand which parts of infrastructure have to be monitored closely, where regulation is necessary and where liberalization can lead to welfare gains by increased competition, and thus lower prices and higher quality. In addition, these findings open up possibilities for governments to privatize state-owned companies while using regulation to prevent excess earnings.

1.4 Empirical Findings

The empirical analyses are based on a set of publicly listed firms which are active in infrastructure sectors. In order to test several of the properties developed within the theoretical part, a sample of firms is developed and each firm assessed regarding its ownership of infrastructure in detail. While a set of 36 countries and 1.491 firms is used in the descriptive part, the set is reduced to 31 countries and 1.210 firms in the empirical part, resulting of missing data. The main set of firms is also used in Rothballer (2012), Rothballer and Kaserer (2012) and Rödel, Rothballer (2012).

In the empirical analyses robust covariance estimators for fixed effects models are applied to treat for heteroscedasticity and serial correlation. The model fit is better for regression on Tobin's Q than on return on assets (ROA). Tobin's Q maps the future expected performance based on the stock market's expectations related to its assets, while ROA displays the current real performance of the firms.

Different empirical analyses are conducted on both dependent variables ROA and Tobin's Q. Therefore explanatory variables are introduced. Firm specific variables are key factors to evaluate the firm, such as the firm's size, growth of sales, debt, capital expenditures or dividends paid to the investors. Country-specific variables describe the demand and purchasing power of the country with variables such as population growth and GDP per capita. The third category of variables are country-sector-specific variables. Here e.g. the Herinfahl-Indicator is calculated for each company, year, country and sector to assess the monopoly power of the firm. Equally indicators for regulation are applied.

The explanatory variables are regressed in an unbalanced panel data analyses on the dependent variables. To examine disparities of sectors, properties and network types, the full set of firms active in infrastructure is split in subsets. The first subset sorts the firms based on the sector, the second subset splits the full set into three parts, one only owning nodes and/or edges, the second owing nodes or edges and additionally offering services and the third containing completely vertically integrated firms. The third subset splits the firms into firms active in undirected networks (firms active in transport and most firms active in telecommunication) and firms active in directed networks(broadcasting, energy and water).

The correlation of the indicator for regulation is negative for correlations on ROA and positive for the correlations on Tobin's Q. Investors seem to assess the long term performance of countries with stricter regulation higher than the value of assets in countries with less regulation, while firms show higher ROA in countries with less regulation.

Significant positive correlations are exhibited for population growth for both dependent variables in almost all regressions. Population growth proxies the increasing demand for infrastructure, because data for demand for specific infrastructure services are available but still is fragmentary. Thus in countries with a growing population the performance of firms increase, while in countries with decreasing population, equally the performance of firms decrease.

Likewise GDP per capita is applied in the models to map the demand based on the purchasing power of the countries. Here most of the correlations are negative. Thus firms in countries with smaller purchasing power do perform better.

Tests on different means of the sectors show, that sectors exhibit significantly different means of ROA and Tobin's Q. Regressions on ROA and Tobin's reveal that the explanatory variables do influence them differently. So sectors do exhibit differences.

Splitting the set of firms in three subsamples, the first only owning nodes and/or edges, the second owing nodes or edges and additionally offering services and the third sample only containing completely vertically integrated firms reveals two important findings. The first set of firms, which only own nodes and/or edges do show positive correlations of the regulatory indicator to the dependent variables ROA and Tobin's Q. These correlations mark that stricter regulation increase the current and expected performance of these firms. An explanation could be that access prices or entry barriers of strict regulation protect the monopolistic situation of these firms.

In contrast the regulatory indicator shows negative correlations for the subsamples of firms additionally offering services and the ones completely vertically integrated. Here less regulation improves the ROA. In the short term, less regulation might increase the market power of the firms, which are now able to exploit economies of scale and scope.

One of the hypotheses developed in the thesis states that firms active in undirected networks do profit more from an increase in demand, proxied by population growth and GDP per capita, then firms active in directed networks. This is based on direct network effects, prevalent only in undirected networks. The correlation of population growth on ROA and Tobin's Q is significant positive for undirected and directed networks. The significant positive correlation shows an higher value for undirected networks. This correlation is supported by the GDP per capita, showing positive correlations on ROA and Tobin's Q for firms active in undirected networks and negative ones for firms active in directed ones.

Market power, mapped by the Herinfahl-Index, shows significant negative correlations in regressions on ROA and insignificant negative ones on Tobin's Q in almost all regressions and sets. An increase in competition increases performance. This could be explained by the incentive competition creates to reduce costs and improve structures and products.

In many of the regressions individual time effects are identified. The time effects on ROA are mostly significant negative, the time effects on Tobin's Q are mostly insignificant positive. These time effects display that the developments of firms active in infrastructure are not mapped sufficiently by the implemented models.

Chapter 2

Infrastructure - Developments in Demand and Financing

The thesis develops an economic definition of infrastructure, which is subsequently used for the econometric analyses. Therefore, the existing definitions of infrastructure and the way the term 'infrastructure' is used in economic research are displayed. The relevance of topics of demographic development, environmental challenges, technological development and economic growth are highlighted to provide a framework for the demand of infrastructure. The thesis proceeds further to the topic how these challenges can be financed privately, describing the players involved, the types of the financial structures and partnerships and expected outcomes.

Infrastructure is often assumed as economic infrastructure, including economically relevant sectors such as transport, energy, electricity, telecommunication but other definitions refer as well to social infrastructure with facilities and services like hospitals, schools and governmental institutions.

2.1 Definitions of Infrastructure

2.1.1 Trends in the Discussion of Infrastructure

In the public discussion, infrastructure is often understood as goods provided by the public due to its characteristics of public goods, economies of scale and scope (see Torrisi (2010) for an extensive overview of this topic). The most often discussed argument is the inevitability of the provision of the good or service for any economic system and its growth as infrastructure services are considered essential for consumers and citizens and are often provided by monopolists (see e.g. Organization for Economic Co-operation and Development (OECD) (2007), p. 13, chapter 2.1.3 for a brief overview of studies analyzing this topic, or Smit, Trigeorgis (2009), p. 81).

For decades in many countries, such as Germany or France, infrastructure has been considered a public good and thus was financed by taxes and provided by the public sector (von Hirschhausen et al. (2004), p. 89). In contrast, in other countries, such as Britain or the US, network utilities where often built by private entrepreneurs (Newbery (2000), p. 18). It is important to highlight that publicly owned infrastructure is not a public good. Public goods are defined as goods where any additional user does not impose additional costs and cannot be excluded from the use of this good[1].

Until recently, comparably to the assumed public good characteristic, networks of telecommunication, electricity, gas and railway were considered to be natural monopolies[2]. It wasn't until the mid-1980s that competition in these networks has been considered to be feasible (Growitsch, Wein (2004), p. 21).

[1]Pure public goods are very rare; one often cited example in this context is a country's army. When an army defends a country, no one can be excluded from being defended. And an additional inhabitant does not impose extra costs when the good is "defense"(see for example Frank (1997), p. 620).

[2]A natural monopoly is a company which has, based on its properties, no natural competitors. The topic of natural monopolies and their characteristics in combination with physical networks will be discussed in more detail in chapter 3.3.

Another challenge in the discussion of infrastructure is that in theoretical and empirical literature "public investment" and "infrastructure investment" are used almost synonymously (see Kappeler, Välilä (2007)). For example, Aschauer (1989b) differentiates between public consumption and public investment, and excludes non-military investments and describes public infrastructure as "roads, highways, mass transit, airports, port facilities and the like" (Aschauer (1989a), p. 17).

Today the discussion of infrastructure also includes infrastructure as an asset class for private investments and research in this area increases, while an adequate definition for infrastructure is still missing (see e.g. Kolodziej, (1996)). Consequently, Torrisi (2009) asks the question: "What is infrastructure? How to measure it?" (Torrisi (2009), p. 102).

2.1.2 Definitions of Infrastructure in Literature

Aschauer (1989a), one of the first researchers to analyze the influence of public investment on productivity growth, followed by many researchers of this time, assumes that "the public infrastructure of roads, highways, mass transit airports, port facilities and the like - is argued to have positive direct and indirect effects on private sector output and productivity growth" (Aschauer (1989a), p. 17). This vague description of infrastructure is common for this type of analysis.

Torrance (2009) splits infrastructure in three different categories: "(1) transport infrastructure, such as roads, rail tracks, and airports with users fees; (2) regulated infrastructure, such as water-, electricity- and gas distribution networks with regulated service contracts with availability fees; and (3) social infrastructure, such as schools and hospitals, for which governments pay an availability fee over a 20- to 30-year term" (Torrance (2009), p. 81). Thus Torrance explicitly includes services and even specific contract types as well as social infrastructure in his definition.

The OECD concentrates its analysis on electricity infrastructure and services, water infrastructure and water-related services, long-term rail freight traffic and its infrastructure as well as urban public transport services (OECD (2007)). But they also mention education and health spending in this context (OECD (2007), p. 23p). A proper definition is not given although problems and requirements are discussed in detail.

Henckel and McKibbin (2010) summarize different types of infrastructure and name internet, telephone (fixed line and mobile), rail, air, sea and road transportation, energy and water. They do not differentiate between sectors and services. But they point out the economic characteristics that there is no perfect competition and ask whether the reason for this is scope, scale or longevity. They recognize network externalities and the fact that infrastructure is not a pure public but a collective good (Henckel, McKibbin, (2010)).

Finally, Fay et al. ((2011), p. 333) define that "infrastructure services are mostly provided through networks, a fact that implies a nonlinear relation with output". But even though Fay et al. mention two studies which focus on the sectors telecommunication and roads, a more detailed definition of infrastructure is not developed. Equivalently, Egert, Kozluk and Sutherland (2009) and Bühler (2004) name infrastructure as networks. Both do not elaborate on the implications of infrastructure and network theory for economic growth, productivity and competition.

Torrisi (2009) provides an extensive overview of definitions of infrastructure and defines infrastructure as a "capital good (provided in large units) in the sense that it is originated by investment expenditure and characterized by long duration, technical indivisibility and a high capital-output ratio"; he proceeds further and assumes that infrastructure is also a public good in terms of the "proper economic sense, that it fulfills the criteria of being not excludable and not rival in consumption" (see both Torrisi (2009), p. 104).

Of those papers that provide a definition of infrastructure only a few also derive implications that logically follow from its definition. Romp and de Haan (2005) and Estache and Fay (2007), for example, identify infrastructure as networks which exhibit network externalities and other economic characteristics. Those characteristics result in market imperfections and government interventions.

In 1970 Weitzman already stated that infrastructure investment has external effects on other industries and defines "productive quick yielding capital" and "indirectly productive infrastructure" on the adjunct sectors (Weitzman (1970), p. 555). He argues that this indirectly productive infrastructure is important for private capital to be productive. To differentiate between these terms I will use the terms productive sector/capital and infrastructure sector/capital. He lists four basic features of these infrastructure sectors and capital (Weitzman (1970), p. 556):

1. Infrastructure capital is complementary to productive capital so that more productive capital only yields higher outcomes with more infrastructure capital investments.

2. The infrastructure sector is highly capital-intense with high capital/labor ratio (compared to the productive sector) and consists of structures and installations.

3. The infrastructure sector has substantial economies of scale in creating capacity.

4. Infrastructure capital, once invested, cannot be changed to productive capital and vice versa.

The arguments 2, 3 and 4 stated will be adopted in the definition of this work and will be related in detail to theory of infrastructure and its economic characteristics. Additional characteristics of infrastructure will be elaborated in detail.

Aschauer (1989a) simplifies Weitzman's argument by pointing out that infrastructure has "positive direct and indirect effects on private sector output and productivity growth" (Aschauer (1989a) p. 17). The direct effect is based on the fact that the availability of public capital supports the production of the private sector (see Aschauer (1989a), p. 17).

The effects investments in transport infrastructure have on an economy are described by Henckel and McKibbin (2010) as direct effects, reducing transport costs and the indirect effects lowering inventories. The indirect effect is based on the complementarity of the infrastructure investments and private capital output. “An increase in the stock of public capital raises the return to private capital which, in turn, serves to spur the rate of expansion of the private sector capital stock” (Aschauer (1989a), p. 17).

These arguments are based on network theory. The definition of economic infrastructure is developed in chapter 3 and refers to infrastructure as physical networks and is related to different economic theories to develop relevant properties of infrastructure. Egert et al. e.g. use the definition as a supporting construct, in ”Infrastructure and Growth: Empirical Evidence” (Egert, Kozluk and Sutherland, 2009), but they do not develop an economic interpretation of the characteristics. Equally to the approach of this paper, Growitsch and Wein ((2004), p. 21pp) apply a similar systematic to infrastructure sectors but do not create a definition applicable to other sectors. Economides (1996) and Economides and White (1994) developed the economics of networks, the theoretical basis for the argumentation of the thesis and applied them to the networks of telecommunication and transport but did not apply the theory to networks in general.

2.1.3 Findings of Empirical Infrastructure Analyses

One of the first papers surveying the impact of infrastructure investment was published by Aschauer in 1989. He finds significant influence of public investment in infrastructure on productivity growth (Aschauer (1989b)). The positive correlation of 0.24% was rejected by several analyses based on empirical drawbacks (see for example Gramlich (1994)). Nevertheless, several studies, which are summarized in the table 1 below, found evidence of a positive relationship between infrastructure, infrastructure investment and productivity and economic growth.

The definitions of infrastructure and the measurements differ as well as the explained variable. Standard publications in infrastructure analyze either sectors, focus on one part of a sector separately or discuss a more aggregate but undefined level of infrastructure. Thus a comparison of these studies cannot be successful.

As will be shown in chapter 2.3, economic growth requires a continually increasing and reliable infrastructure. Two ways to assess the impact of economic growth on infrastructure can be differentiated. In the first case infrastructure is a direct factor of production, so that the direct influence of infrastructure for production is determined. The second case assesses the influence of infrastructure on total factor productivity and thus measures the indirect effect on production (see Crafts (2009), p. 332). Crafts suggests the following growth equation:

$$Y = A(K_{pub})f(K, L, K_{pub})$$

Where Y is the GDP, $A(K_{pub})$ equals the indirect influence the infrastructure has on the total factor production and $f(K, L, K_{pub})$ equals the direct effect, indicating that infrastructure is to be treated equally to capital (K) and labor (L) in the production function of a country (see Crafts (2009), p. 332).

Cost-benefit studies show welfare gains of improvements in transport, which are based on the reduction of congestion and caused by time saving (Crafts (2009), p. 330). This welfare gain is based on a market failure which is not internalized by the passengers. When increasing quantity and quality of transport, the impact of a single passenger on others is decreased (see Crafts (2009), p. 330).

Almost all empirical analyses emphasize the fact that the influence of infrastructure on economic growth cannot be determined confidingly but the development of infrastructure could be adversely influenced by economic growth. The direction of the correlation between infrastructure and growth is not determined irrevocably (see e.g. Czernich et al. (2011), p. 506). In the sector of telecommunication omitted variables, like the ability and the willingness to pay for broadband access, or substitutes of the state for broadband internet penetration in regard to promote economic growth, distorts the empirical analyses (see e.g. Czernich et al. (2011), p. 506). Additionally, technology adoption is highly correlated with economic development measured by per capita income. So causes and correlations are complex to determine with a high degree of certainty (Comin, Hobjin, Rovito (2008), p. 253).

Since infrastructure and infrastructure investments are not reported in detail, empirical studies often focus on public expenditure or public investments. Both are found to improve the economic output and multiple generations by expanding the publicly invested capital stock (Peree, Välilä (2005), p.5).

Table 1 gives an overview of some relevant empirical studies in the area of infrastructure investments and its influence on growth, costs and productivity.

Table 1: Empirical Findings on Effects of Infrastructure on Growth, Costs and Productivity.

Authors	**Journal**	**Titel**	**Topic**	**Findings**
Aschauer (1989)	Journal of Monetary Economics	Is Public Expenditure Productive?	Non-military public capital stock versus public expenditures (military vs non-military) on productivity.	Public capital stock has highest explanatory power, with focus on streets, highways, aiports, mass transit, sewers, water systems, etc.
Berndt, Hansson (1992)	Scandinavian Journal of Economics	Measuring the Contribution of Public Infrastructure Capital in Sweden	Influence of public infrastructure capital (highways, airports, mass transit facilities, water supplies, sewer systems, police and fire stations, courthouses and public garages etc.) on private sector output and productivity growth in Sweden.	Increases in public infrastructure reduce private sector costs; excess public infrastructure has been falling since 1980s.
Morrison, Schwartz (1992)	NBER Working paper Series	State Infrastructure and Productivity Performance	Impact of infrastructure (highways, water and sewers) investments on firms' productivity.	Infrastructure investment is important to firms' costs and productivity growth.

Table 1: Empirical Findings on Effects of Infrastructure on Growth, Costs and Productivity. (continued)

Authors	**Journal**	**Titel**	**Topic**	**Findings**
Nadiri, Mamuneas (1994)	Review of Economics and Statistics	The Effects of public infrastructure and R&D capital on the cost structure and performance of U.S. manufacturing	Influence of publicly financed infrastructure (all governmental investments in real estate and structures, excluding military investments) and R&D investments on cost structure and productivity performance of manufacturing industries.	Both investments have significant positive effects.
Holtz-Eakin, Lovely (1996)	Regional Science and Urban Economics	Scale Economies, Returns to Variety, and the productivity of public infrastructure	Productivity of public infrastructure, tested with state level panel data.	No direct but indirect effects of public capital on productivity in manufacturing.
Hulten (1996)	NBER Working Paper Series	Infrastructure Capital and Economic Growth: How well you use it may be more important than how much you have	Efficiency in use of infrastructure (telephone systems, road networks, electric power systems, railroad and irrigated land area) in low and middle income countries.	Inefficiency in infrastructure use leads to smaller benefits of infrastructure investments.
Lee, Anas, Oh (1999)	Urban Studies	Costs of Infrastructure Deficiencies for Manufacturing in Nigerian, Indonesian and Thai Cities	Electric power, water, telecommunication, transport, waste disposal deficits on manufacturing in Nigeria, Indonesia and Thailand.	Variation between countries and firm size.

Table 1: Empirical Findings on Effects of Infrastructure on Growth, Costs and Productivity. (continued)

Authors	**Journal**	**Titel**	**Topic**	**Findings**
Reinikka, Svensson (1999)	World Bank Policy Research Paper	How Inadequate Provision of Public Infrastructure and Services Affects Private Investment	Microeconomic evidence to show the effects of poor infrastructure services on private investment in Uganda, proxied by inadequate power supply.	Inadequate infrastructure reduces productive private investment, based on the necessity to invest in expensive substitutes to inadequate existing services.
Bougheas, Demetriades, Morgenroth (1999)	Journal of International Economics	Infrastructure, Transport Cost and Trade	The paper assumes that transport costs are depending on the level of (itself) costly accumulation of infrastructure. The level of infrastructure should be positively correlated with the volume of trade	Data of European countries support the assumption that the level of trade is positive correlated with the volume of trade.
Röller and Waverman (2001)	The American Economic Review	Telecommunications Infrastructure and Economic Development: A Simultaneous Approach	Influence of Telecommunication networks on economic growth, 21 OECD countries, 20 year period;	Significant positive causal link.
Ghosh, Meagher (2005)	SSRN	Political Economy of Infrastructure Investment	Infrastructure investment as endogenous variable in a setting of consumer preferences and infrastructure reducing transport costs and indirectly affect market power.	In less developed countries, competition is the prerequisite for the public to support governmental investments in infrastructure.

Table 1: Empirical Findings on Effects of Infrastructure on Growth, Costs and Productivity. (continued)

Authors	**Journal**	**Titel**	**Topic**	**Findings**
Engel, Fischer, Galatovic (2006)	NBER Working Paper Series	Renegotiation without holdup: anticipating spending and infrastructure concessions	Renegotiation of infrastructure (highway) concessions as tool in election campaigns.	Renegotiating increase spending and allow the incumbent to spend future income of taxpayers today.
Czernich, Falck, Kretschmer, Woessmann (2011)	The Economic Journal	Broadband Infrastructure and Economic Growth	Effect of high speed internet access on economic growth on a panel of OECD countries, covering 1996-2007.	Increase in broadband access of 10% leads to annual per-capita growth of 0.9-1.5%.
Escribano, Guasch, Pena (2010)	World Bank Policy Research Working Paper	Assessing the Impact of Infrastructure Quality on Firm Productivity in Africa	A cross country comparison of the impact of infrastructure quality (provision of custom clearance, energy, water, sanitation, communication) on total factor productivity of African manufacturing firms.	Poor quality electricity provision, losses from transport interruptions and water outages effects poor countries, custom clearances are of problem for faster growing African Countries.

Barro (1991) summarizes the positive findings of infrastructure investments on growth to be the effect the investment of the government has by raising the returns of private investments in the long run. He emphasizes that this increase has to be greater than the one caused by increased taxes (Barro (1991)).

A second topic to be kept in mind are welfare effects (e.g. better health as a result of a higher qualitative water infrastructure) infrastructure has on the community in contrast to the here in detailed surveyed effects on economic growth and efficiency.

2.2 Contemporary Developments in Infrastructure

The introduction and the overview of empirical findings highlighted the importance of infrastructure in a qualitative and a quantitative way. The next chapters summarize the increasing demand for infrastructure resulting from improvements and extensions. I will also discuss the development of governmental investments in infrastructure, the resulting financial gaps and an overview of possible investors, financing structures and partnerships.

Demographic development, economic growth and other factors are increasing the necessity for investments in infrastructure. This, combined with tightened public budgets has been increasing the importance of private financing of infrastructure for the last years. Means for that are privatizations by going public; but simultaneously infrastructure funds, private equity firms and companies, and often multinational enterprises (MNEs) emerged investing in infrastructure. Pension funds discovered infrastructure investments as long-term investments when the real estate bubble burst and the economic crisis started in 2008 (see e.g. Davis (2008), or Torrance (2009); Smit, Trigeorgis (2009), p. 81). The incentive for investors to put their money in infrastructure is based on the assumption that "operational infrastructure investments, such as airports or toll roads [...] involve rather stable cash inflows over a long-term horizon" (Smit, Trigeorgis (2009), p. 81).

2.2.1 Increasing Demand for Infrastructure

In most of the OECD countries the existing infrastructure is sufficient at the current level, although investments in maintenance and quality improvements, as well as increasing capacity are constantly requested. This is in contrast to developing countries, where still an increasing demand for infrastructure investments in terms of construction, based on economic and social expectations and needs is pressing. Three main drivers of an increasing demand for infrastructure can be identified:

- demographic development;
- environmental challenges and drivers;
- technological change;
- economic growth and reliability.

These topics will be discussed in detail in the next paragraph.

2.2.1.1 Demographic Development

The first point to be discussed is demographic development. In all OECD countries, the population is aging, meaning that fewer children are born and people get older because of better nutrition, improved health services and healthier life styles. The aging population has different effects. First, older people show different behavior with regard to infrastructure. Retired people tend to use public transport more often than driving their own car, thereby increasing the demand for public transport and decreasing the demand for individual transport means (see Andrieu (2007), p. 157).

The second important effect of an aging population are the increasing constraints on public budgets. A growing retired population contributes less to local and national taxes (Andrieu (2007), p. 154, Stevens, Schieb (2007), p. 39). Additionally, costs for health care, long-term care as well as the need for support of lifetime learning strains the public budget further, tightening the budget available for (economic) infrastructure investments (Stevens, Schieb (2007), p. 23 pp).

The third factor of demographic development is the ongoing urbanization (see Stevens, Schieb (2007), p. 29). The trend towards megacities and the abandonment of rural areas especially by young and educated people create problems in scarcely populated areas and their access to adequate infrastructure as well as congestion problems in the crowded cities. For example telecommunication services in remote areas are important for the remaining population but are expensive to implement due to the low number of users compared to high investment costs. In contrast, cities need more infrastructure but face scarcity in space (see Andrieu (2007), p. 157).

The fourth topic of demographic development is the growing population on the global level which increases the strain on the capacity of the existing infrastructure. This is especially severe for sectors with scarce resources like for example the water sector (see Andrieu (2007), p. 156). Other important examples in this context are energy and electricity imposing several environmental questions.

2.2.1.2 Environmental Challenges and Drivers

It is common knowledge that CO_2 emissions cause climate change. According to Davis, Caldeira and Matthews (2010), greenhouse gas (GHG) is emitted either directly or indirectly by infrastructure. GHGs is directly emitted to the atmosphere by any energy infrastructure. The second type of emitting infrastructure, highways and the infrastructure of refueling "contributes to the continued production of devices that emit GHGs to the atmospheres" (Davis, Caldeira and Matthews (2010), p. 1330). In their study they analyze the impact of the existing energy consumption on climate change. Therefore they assess the existing energy infrastructure (power plants, motor vehicles furnaces) and extrapolate their GHGs emissions for their standard lifetime. They find that if no new infrastructure and devices are built, the warming would be below 0.7C, which is doubtful (Davis, Caldeira and Matthews (2010), p. 1333), based on further demand for transport and electrical devices in undersupplied developing countries like Brazil, China or India.

As climate change and the increasing prices for oil, gas and coal (which are the main sources for industrially produced CO_2) indicate, new ways of generating electricity are necessary. Jacobson, Delucchi (2011) summarize them in wind, water and sun (WWS). In their study they show that it is technically feasible to generate the necessary energy of the world with WWS by 2030. But they are also aware that WWS provides variable output, which is in sharp contrast to the increasing demand for reliable energy and electricity supply in globalized economies. They state that this is only feasible when large scale investments are made (see all Jacobson, Delucchi (2011), p. 1155). Two topics have to be differentiated: the operation of the electricity system and the systems of energy generation[3].

These investments would have to cover different parts of the network to satisfy the set goals. The electricity-system operators use an automatic generation control, which balances short-term respond changes (seconds and minutes), spinnings, which supports short- and mid-term changes (minutes and hours), and peak power generation, which balances long-term (hourly) changes. The first two, automatic generation and spinnings, are cheap to purchase as well as to operate and maintain, while peak power generation is expensive. This system is especially important for WWS systems as supply varies strongly over days and seasons so that additional, to the standard systems with constant energy generation required peak adjustments are needed and gap adjustments become necessary (see all Delucchi, Jacobson (2011), p. 1170). Here the amount of invested capital is especially high.

But WWS also have advantages in their short downtimes compared to the traditional energy plants of oil, coal, nuclear and geothermal. WWS show naturally shorter maintenance times and are less often confronted with shutdowns of extreme events (for example the shutdown of a nuclear plant because of a heat wave and a severe increase of the temperature of the cooling water). Additionally, when maintenance

[3]The WWS technologies summarized in this study are wind (wind turbines), wave (surface waves), geothermal (steam and hot water from the interior of the earth provides heat, and generates electricity in power plants), hydroelectricity (water power plants, based on gravity), tidal (tidal turbines), solar photo-voltaic, concentrated solar power (solar heated fluids are converted into electricity) (see all Jacobson, Delucchi (2011), p. 1157).

occurs, only one solar panel or one wind turbine has to be shut down and not the whole plant (see all Delucchi, Jacobson (2011), p. 1171).

To enable WWS to serve the energy demand properly and reliably, (see all Delucchi, Jacobson (2011), p. 1171) suggest several points involving necessary investments:

- The interconnection of areas with different viable energy sources;
- the implementation and utilization of non-variable energy sources like hydro energy, tidal power (predictable) and geothermal supply to fill gaps and peaks;
- the introduction of a smart demand-response system to be able to balance the variable supplies properly;
- the storage of electricity power at the generation side or in electricity-vehicle batteries;
- oversizing the maximal capacity of WWS generation to avoid times where demand is higher than supply so that e.g. hydro energy has to fill the gaps; and
- the use of weather forecasts to improve planning of the energy generation.

Two other environmental challenges based on climate changes within infrastructure have to be mentioned. The first is the so-called e-mobility, describing the switch to electrically fueled cars to reduce CO_2 emissions. The second topic is water desalinization, which becomes important because of increased water needs and the decreasing supply of fresh water caused by climate change. All these issues need high investments.

2.2.1.3 Technological Development

The development of telecommunication technology resulted in rapidly increasing demand for telecommunication services over the last years. In 2001 there has been a question whether there is any need to expand the telecommunication network further (see e.g. Röller, Waverman (2001), p. 911). In contrast today there is an emerging discussion on how to restrict access or expand capacities to meet the increasing demand of technological development in telecommunications. This increased demand is based on the development of the internet and its increasing use. When the internet first became popular outside the scientific community, mainly texts and, only rarely, pictures of low quality were shared. Today people stream TV shows over the internet and listen to internet radio. Cloud computing increases data transfer to and from servers on a global level instead of a data management on stationary personal computers. The discussion focuses on restricted access, where data packages can be treated preferentially, especially in times of high demand[4] and, in contrast, on topics of expanding capacities and quality by broadband access, all-glas fibres and LTE technologies (long term evolution, wireless telecommunication standard for high speed data). This development is not only important for private households but also for firms that are active in different countries and are communicating on a daily basis and accessing the same documents on international server platforms.

Water and drinking water also face emerging challenges, that are becoming more severe due to climate change, especially in arid areas. First, an increasing world population needs more fresh water to survive and to irrigate agricultural fields to maximize yields. Second, production processes require vast amounts of water, for example carbon, steel or textiles. This water then has either evaporated or become polluted and has to be treated to be used again (see e.g. Andrieu (2007) p. 156). Increasing aridity caused by climate change intensifies these problems, especially in Africa or Australia. Desalination plants can decrease these problems but need a vast amount of energy and are expensive to build.

Energy is another important factor which will be requested in a higher amount but also in a different way. As of today most of the energy is generated by the use of oil, gas and coal. Burning these energy sources results in the emission of CO_2, as presented in the last chapter, which is the main driver of climate change. So there is a need to invest in energy sources to more climate friendly types like wind, sun,

[4]See e.g. Shrivastava et al. (2011) for a discussion on algorithm to organize demand and supply in a more efficient way.

water and biomass. Storage of energy in huge amount is today only possible in water reservoir power stations, which are seldom. Building new ones is expensive and time consuming as well risky since they might impose as they might impose environmental changes by flooding and destroying valleys (Ibrahim et al. (2008), p. 1222).

2.2.1.4 Economic Growth and Reliability

The ongoing increase in economic growth especially in China, Brazil and India, further increases the demand for infrastructure (Stevens, Schieb (2007), p.20). Several topics have to be distinguished here.

Economic growth pushes the demand for infrastructure per se. Transporting the demanded goods requires an expanded and reliable transport network. This development is enlarged by the disjoint production of goods in the globalized economy. Goods assembled cheaply in China have to be transported to the markets where they are sold for high prices. This does not only concern roads and airports, but also the cheaper but slower transport via ships. The main ports all over the world today face capacity constraints and keep expanding their capacity steadily (see e.g. De Borger et.al (2008), p. 528, Maloni, Jackson (2005), p. 1pp).

World trade grew on average 5.9% per year between 1950 and 2005 (Hummels (2007), p. 131). Following a negative world trade growth of 12.5% in 2008, growth recovered in 2009 and increased to a rate of 12.5% and since then shows positive rates of about 2% per year (OECD, (2013)). Different topics are of interest here: costs, technological change and quality. The reduction of transport costs is due to technological change in all transport sectors within time and increased in the intensity of trade. Likewise the demand of expensive air transport in contrast to the cheaper shipping transport grew (see all Hummels (2007), p. 131). Hummels (2007) argues that indeed transport costs did not fall, based on a change in input costs (see all Hummels (2007), p. 132) and unmeasured quality changes in transport and loading times[5](see Hummels (2007), p. 144). The increase in input costs not only includes fuel prices but also ship prices and port costs, which, according to Hummels were "skyrocketing" (see Hummels (2007), p. 145). In contrast, the technological development in air shipping decreased costs and thus increased the share of this fast type of transportation ((see all Hummels (2007), p. 151 pp). This short insight into the history of air and ship trade shows how fast trade adjusts to demand and new production structures. "New trade patterns alter the weight/value composition of merchandise, change the demand for timeliness, increase production fragmentation and generate further demand for transport services." (Henckel, McKibbin (2010), p. 4). As Henkel and MacKibbin (2010) argue further, these changing demand structures also require new infrastructures, with new connections and nodes and more complex and sophisticated structures (Henckel, McKibbin (2010), p. 4). Additionally, globalization increases the need for countries to stay competitive with regard to their infrastructure and its reliability.

For telecommunication globalization is equally an important challenge. Dispersed information and distributed production rely on reliable communication means and data transfer. Technology development for example can be based in the Silicon Valley connected with worldwide distributed partners, the production takes place in several Asian countries in several companies, finally the product is sold worldwide. To be able to gain returns in this complex system, development, production and distribution as well as the logistics have to be orchestrated within a reliable communication system. While within local companies there might exist some internal infrastructure, they still rely on public telecommunication infrastructure when communicating between states, countries and continents. And with increasing economic growth, trade and complexity, the data volume which has to be transferred reliably and fast increases, too (see e.g. for the importance of broadband infrastructure on economic growth Czernich et.al (2011)).

Economic growth, when including an increased energy need and an increase in produced goods, also requires increased water within the production procedures. The

[5]This is especially attributed to the development of containerization. This shortens the loading times but also had immense costs for implementing the necessary loading technologies for ports and ships.

water used in production or for energy generation (e.g. in terms of fracking) has to be treated to gain environmentally safe effluent. The newly developed sewage treatments are able to generate effluent safe for drinking water, a technique which is not used by default today. Grossmann and Krueger (1995) provide a detailed study, tracking different factors of water (and air) pollution and find, that pollution does not necessarily worsen with GDP growth but does so in low-income countries. They argue that pollution is decreased by the investment in cleaner technologies in countries with higher income and that the impact of economic growth on water (or air) quality per se cannot be determined by the data available.

But the expansion of the capacity of each single infrastructure is not always the best solution. Andrieu (2007) suggests three parameters to be considered in terms of infrastructure investments:

1. do social and political objectives support a restricted access and use of infrastructure services;
2. is there an overall public goal which can be instrumentalized to switch use other types of infrastructure services and thus reduce capacity bottlenecks;
3. can infrastructure systems be improved to increase capacity cheaply (Andrieu (2007), p. 154).

Andrieu (2007) identifies three areas which have to be considered in the development of infrastructure:

- "Economic objectives. The provision of services needs to be effective, efficient, reliable and resilient, and should also contribute to improving the competitiveness of the economy [...].
- Social objectives. The service provided may have a strong social dimension either because it is essential for life (e.g. clean water), and/or it has strong positive externalities (e.g. urban public transport).

- Environmental objectives. The provision of services may have an adverse environmental impact which needs to be taken into account (e.g. road transport, electricity)" (Andrieu (2007), p. 111).

The existence of infrastructure systems and their sufficient capacity are important; equivalently, it is necessary that infrastructure systems are reliable. Electrical blackouts or the failure of the telecommunication system as well as the congestion of transport systems lead to reduced in economic growth.

A study of production companies in Africa shows that the unreliability of electrical infrastructure imposes the need for companies to install emergency backup generators to be independent of frequent blackouts. But this is feasible only for bigger companies; smaller companies face regular electrical blackouts and thus losses in production and in the long term in their sales figures (see all Reinikka, Svensson(1999)). The more the different parts of infrastructure are connected with each other, all requiring electricity, using telecommunication systems in transport systems and so on, the more reliable these systems have to be. Furthermore people expect higher quality standards of the systems (see Stevens, Schieb (2007), p. 21).

In the future the reliability of the systems and their ability of "keeping the lights on", that is keeping goods, people and information moving, will be of even higher importance (see Stevens, Schieb (2007), p.55).

Moreover, economic growth not only influences the welfare of each individual country but also of its neighbors (Henckel, McKibbin (2010), p. 4). This effect results in an integration of trade partners etc that infrastructure integrates trade partners and thus spurred economic growth in both countries (Roberts, Deichmann (2009)).

2.2.2 Infrastructure Financing - The Financial Gap

2.2.2.1 Government Spending

Based on the OECD Infrastructure Project, investments for infrastructure in telecommunication, roads, rail, electricity and water should account on average for 2.5% of the world GDP (see Stevens, Schieb (2007), p. 21). Adding oil, gas and coal investments, this should account for 3.5% of the world GDP, not including ports, airports and storage facilities (see Stevens, Schieb (2007), p. 22).

Even though in most of the OECD countries the focus will be on maintenance and upgrading instead of planning and building new infrastructure, the OECD Infrastructure Project expects that investments in electricity transmission and distribution should more than double to meet the needs until 2025/30; in road construction it would have to double almost, equivalently to water supply and treatment. And investments in rail infrastructure will have to increase by one third until 2020 (see all Stevens, Schieb (2007), p. 21). In contrast, the BRICS countries (Brasilia, Russia, India, China, South Africa) will have to face the construction of new infrastructure to expand their inadequate networks (see Stevens, Schieb (2007), p. 21).

But government spending on infrastructure decreased considerably over the last 20 years, starting with 9.5% in 1990, decreasing to 8% in the mid-1990s and being at a low of 7% of GDP in 2005. In contrast the expenditures for social tasks increased within this period (see Stevens, Schieb (2007), p. 22, Crafts (2009), p. 327). Additionally governments are reluctant to impose higher taxes, especially close to elections (see Stevens, Schieb (2007), p. 21). In Europe, the Deficit Rule of the Stability and Growth Pact (SGP) results in a further decline in public investments (Peree, Välilää (2005), p.5). Excluding investments in the generation of capital stock from the SGP would induce over-investments in capital stock related investments imposed by political re-election presents. On the bottom line the high overall debt might lead to macroeconomic destabilization (Peree, Välilää (2005), p. 7pp).

A severe problem in determining the investment gap for infrastructure lies in the lacking definition of infrastructure and the lacking decomposed data on public investments. As Kappeler and Välilä (2007) summarize, the public investment, including changes in inventory, is composed of the gross capital formation and includes infrastructure, hospitals, schools, public goods and redistribution (Kappeler, Välilä (2007), p. 4 pp). Water supply and waste management are categorized as redistribution and public goods (Kappeler, Välilä (2007), p. 5 pp). They suggest to differentiate between public expenditures as producing “public inputs” for the production procedure of private firms, opposed to consumption expenditures (Kappeler, Välilä (2007), p. 12 pp).

Nevertheless, public expenditures for assets are decreasing world wide, while the demand for reliable infrastructure with high capacity and quality is increasing and thus increases the demand for investments.

2.2.2.2 Fees

Fees are, besides the public budget, one way to meet the costs necessary for infrastructure investments, although they usually do not cover the costs (Stevens, Schieb (2007), p. 40), and especially do not include the costs every additional user imposes, e.g. the increase in traveling times for all other users (Subprasom, Chen(2005), p. 3884). Stevens and Schieb (2007) assume that in the long term direct user fees are the most sustainable solution for the funding of infrastructures. But politicians often hesitate to introduce user fees, based on re-election issues and because it often seems to be an impractical solution (see Stevens, Schieb (2007), p. 42). Taxes can be successful when they are implemented on a local or regional or national level ((see Stevens, Schieb (2007), p. 43). But they also consider subsidies necessary to achieve social equality between different regions (see Stevens, Schieb (2007), p. 41).

They suggest so-called innovation bonds. The revenues for these bonds are directly generated from tolls and fees, and are in contrast to the standard general-obligation bonds, which are usually served from the municipal’s revenues (see Stevens, Schieb (2007), p. 43).

While fees enable the reduction of congestion problems and the financing of the infrastructure, publicly owned companies have objectives which impede the introduction of fees. Fees, set to meet financing needs and prevent congestion are avoided to please voters and supporters (Henckel, McKibbin (2010), p. 5).

2.2.2.3 Private Participation

Private participation in infrastructure investments can play an important role to fill the investment gap. Two types have to be differentiated, one is the privatization of an already existing infrastructure company, and the second is the financing of new infrastructures assets, so-called greenfield investments. The type of investment often depends on the sector of investment. Investments in the energy and telecommunication sectors is through greenfield investments, in the sectors transportation and water often concessions for different types of construction, ownership, maintenance or operation are emitted (see e.g. Hammami et al. (2006), p. 12 or Doh et. al (2004), p. 239pp).

Infrastructure for long has been assumed to be a natural monopoly so that it was largely financed and owned by governments. Only in the US and the UK rail and telecommunication networks have been owned and financed privately, especially in the first year of market introduction (see e.g. Vogelsang (2003), p. 831). Since the 1980s the OECD countries sold assets worth more than US$ 1 trillion to private companies; most of them were infrastructure assets. In non-OECD countries, state-owned assets in infrastructure worth some US$ 200 billion were sold (see Stevens, Schieb (2007), p. 25). So today a growing part of infrastructure is in private hands, especially telecommunication, power generation and railways (see Steven, Schieb (2007), p. 22).

Privatization describes the divestment of government enterprises and the transfer of the ownership rights to one or several private companies (Gil, Beckmann (2009), p. 10). In contrast there is private financing, where concessions for construction, ownership or operation are issued; usually this is summarized in the terms private financing initiative (PFI) or public private partnerships (PPP) and in the practice of outsourcing or contracting out (Gil, Beckmann (2009), p. 10). The success of privatization depends on different factors: the general political development, the general economic conditions, the interest of the general public in shares offering, the level of maturity of the market as well as the capacity and interest of institutional investors such as pension funds and insurance companies to support privatization (Stevens, Schieb (2007), p. 30).

However, as Gil and Beckmann (2009) state: "Recent collapses of privatized enterprises - such as of the British private owner of rail infrastructure, Railtrack, in 2001, and of the London underground concessionate, Metronet, in 2006 – demonstrate that both, running an infrastructure enterprise and writing fair, long-term contracts are challenging undertakings" (Gil, Beckmann (2009), p. 10). For example in France EUR 45 billion of assets are already privatized, but there is still a capacity of EUR 100 billion of infrastructure assets to be deinvested (Stevens, Schieb (2007), p. 30).

Private players are today entitled to build, operate, finance and own infrastructure, but contracts with the public might determine the transfer of the infrastructure after a specific time to the public (Dailami, Leipziger (1997), p. 6). Private investors are a loophole to provide infrastructure in times of strained budgets without raising taxes or issuing bonds (Gil, Beckmann (2009), p. 7). They create innovative financial instruments (Torrance (2009), p. 94) to suffice the high up-front investments and the long-term horizon of returns. Another advantage of private enterprises is that their main focus lies on the profit, so it forces them to be more efficient, cost-conscious, customer-focused and to deliver faster than governmental companies do (Gil, Beckmann (2009), p. 7). Additionally infrastructure investments are assumed to be inflation-proof (Gil, Beckmann (2009), p. 12).

Infrastructure investments rely heavily on participation of the private capital markets for the financing and especially for the managerial competence (Marques, Berg (2011), p. 925).

Infrastructure investments are assumed to show specific properties, the relevant literature summarizes the following properties[6]: they are capital intensive and tied to the region in which the investment is made. The investments can hardly be relocated to other uses and show high sunk costs. The investments are recovered over a long period and often meet basic social requirements. Infrastructure investments

[6]These properties are correct and can be traced back to the definition of infrastructure as proposed in this thesis. The properties and its economic implications thus are highlighted in more detail in chapter 2.4.

are assumed to be vital for economic and social growth. It is assumed that no managerial skills are needed to generate cash flows, based on low variable costs (see all Sawant (2010), p. 1038p). For example the network for underground pipes for water transportation requires high capital investments, the durability is extensive (up to 100 years and more), once constructed it cannot be implemented in another place and almost no substitutes exist. So it is difficult to impose competition by entering and exiting the market without enormous losses. This is the reason why infrastructure industries often face regulation (Gil, Beckmann (2009), p. 12, p. 16).

Private investors expect returns on their investments (Torrance (2009), p. 76). One advantage of infrastructure investments is that the returns vary geographically so that this can be seen as a type of geographic risk diversification (Torrance (2009), p. 94). Another important feature of infrastructure are the low price elasticities, which decrease weighted average cost of capital (WACC) and the return on equity (Regan, Love, Smith (2013), p. 337).

Infrastructure investments are assumed to have stable long-term cash flows with a low market and total risk. Rothballer and Kaserer (2012) tested these hypotheses, based on a data set of publicly listed companies[7]. They find that companies active in infrastructure show indeed a lower market risk compared to the MSCI All Country World Index and thus benefit the portfolio diversification (Rothballer and Kaserer (2012), p. 95, 100). But their analysis shows further that the total risk is not lower compared to the market, based on high idiosyncratic risks (Rothballer and Kaserer (2012), p. 95, 98). Reasons for the higher idiosyncratic risks can be found in the different risks infrastructure faces, such as construction risk, the operating leverage, the exposure to regulatory changes and the lack of product diversification (Rothballer and Kaserer (2012), p. 95, 102). This is also supported by the finding that, when differentiating towards the sectors, they show different risk profiles (Rothballer and Kaserer (2012), p. 95).

[7]This set of public listed companies is used equivalently in chapter 5, the empirical part of this paper.

2.2.2.4 Cycles of Infrastructure Projects

Within planning, construction and operation of infrastructure huge investments are made, covering long periods. Although there is still an overwhelming presence of the government in the ownership, operation and regulation of infrastructure (see Stevens, Schieb (2007), p. 69), it is useful to assess the different cycles prevalent in this area.

Infrastructure cycles	30 years (Stevens, Schieb (2007), p.70) (10 to 30 years to regain investments based on Dailami, Leipziger (1997), p. 6); (50 years and more durability according to Gil, Beckmann (2009), p. 12);
Business cycles	7 years
Political cycles	4-5 years
Political budgetary cycles	1-3 years

(see for all not directly indicated details Stevens, Schieb (2007), p.70)

This short overview demonstrates the importance of long-term planning of infrastructure projects, which conflicts with the political decision-making cycles and, more severely, the political budgetary cycles. According to Stevens and Schieb ((2007), p. 70) infrastructure investments need a long-term planning and budgetary cycles of 10 to 20 years; other researchers suggest 10 to 30 years and 50 to 100 years durability (Dailami, Leipziger (1997), p. 6; Gil, Beckmann (2009), p. 12).

This aspect is highlighted in a study on airports and the increasing commercialization of airports. While the main functions of airports are control and administration of the airport and air travel, increasing revenues are generated from commercialization. Today in fact the commercial revenues are the single largest source of revenues, according to Freathy and O'Conell ((1990), p. 589). In contrast the traditional functions of airports, control and administration are still in public ownership or an appointed body of the public ownership, generating aeronautical charges, which attribute a decreasing share of the overall revenues (Freathy, O'Conell (1999), p. 589).

The increasing importance of revenues from commercialization and the decreasing aeronautical charges have to be integrated in long-term planning of airports and the ideal area utilizable for commercial activities. This is especially true as the demand for air transport was increasing between 1980 and 1990 (see Freathy, O'Conell (1999), p. 588) and is still increasing. Thus long term planning anticipating future revenue sources and possibilities is immanent in the infrastructure sector. Henckel and McKibbin (2010) expect that governments are not able to anticipate and respond to constantly changing demands on infrastructure (Henckel, McKibbin (2010), p. 4). Thus, private participation other than public provision may prove beneficial, also in regard to the life cycles of infrastructure.

2.2.3 Players in Private Infrastructure Investments

Different players are active in infrastructure investment and will be discussed in the next chapters. For example several private players showed interest, when Thames Water (the London Water Company) was sold in 2006. There were investment banks (e.g. Macquarie), representing institutional investors, managers of infrastructure funds and private equity firms (Torrance (2009), p. 76).

Although currently the main investors in infrastructure are governments, other players show increasingly interest in infrastructure investments, like utility enterprises, mostly in multinational enterprises (MNEs) as well as institutional investors like pension funds or insurance companies. The players will be discussed in this chapter, as basis for the discussion of the partnerships of these players involved and the financing structures installed.

2.2.3.1 Enterprises

Listed and unlisted companies, active in a multinational space, participate in infrastructure investments. This is mainly true in the field of telecommunication and energy. The focus of this thesis will be on listed enterprises. Within a set of listed companies active in infrastructure, the share of companies active in telecommunication and energy was 82% of the total set in the year 2008, covering all OECD countries[8].

"There is also a premium on name recognition and reputation in the field, which explains why in the power sector, for example, large well-known companies such as Honeywell, Siemens, ABB, and Enron[9] dominate the market for independent power producers" (Dailami, Leipziger (1997), p. 5).

Enterprises use different structures of financing infrastructures, corporate finance or project finance. Corporate finance, where the infrastructure is built as an investment within the companies businesses allows adjustments. In project finance the infrastructure project is treated independently from other business activities. This topic is discussed in more detail in the chapter on project finance. Often infrastructure projects are conducted in partnerships with governments. This topic will be treated in detail in the chapter on public-private partnerships.

2.2.3.2 Institutional Investors

Typical institutional investors are banks, insurance companies, retirement or pension funds, hedge funds, investment advisers and mutual funds or private equity funds. These players with high investment capacities are also starting to become active in infrastructure investments.

Pension funds in the OECD increased their budgets from US$ 13 trillion in 2001 to US$ 18 trillion in 2008, which equals an increase of 72% (Stevens, Schieb (2007) p. 26). So pension funds have a huge amount of money which usually is invested in the long term. Pension funds are typically looking for long term investments, which makes infrastructure investments especially attractive. Today, the second largest pension fund, ASB, has a size of EUR 200 billion and invests less than 1% in infrastructure (Stevens, Schieb (2007), p. 37). So the example pension fund ASB still shows large capacity to invest in infrastructure. Most pension funds invest

[8] This number is based on the empirical set of companies used in this thesis.

[9] Enron filed insolvency in 2001.

through funds and co-investment; only in Canada direct investments are possible based on regulations of pension funds (Stevens, Schieb (2007), p. 38).

One way of pension funds, insurance companies etc. to invest in infrastructure are private equity funds. Private equity funds are increasingly looking for investment opportunities in infrastructure (Kaplan, Strömberg (2008), p. 6). According to Page et al. (2008) private equity funds invested 80 billion US$ to 130 billion US$ in public private partnerships.

Private equity funds, as opposed to hedge funds, invest in portfolio companies in the long term (between 7 and 15 years), they are involved in the management and the development of the company and are able to foster greenfield projects. Private equity funds are closed funds so that the investors can only withdraw their money at the end of the fixed period. Investors are so called limited partners, with almost no influence on investment or management decisions. Managers of the private equity firm managing the investments of the private equity fund are general managers. The general managers get managerial fees, based on the committed capital, a rate of the capital employed and carried interests - a share of the funds' profit. General managers usually invest a share of the private money into the fund. Most of the investments are highly leveraged (see e.g. Achleitner, Kaserer (2005), Kaplan, Strömberg (2008) or Page et al. (2008)).

The time horizon of private equity funds of up to maximal 13 to 15 years generates challenges within public private partnership. The construction of infrastructure takes 3 to 5 years at minimum, followed by a start-up time in operations until revenues are generated. Thus governments are in charge to support follow-up-contracts or find other solutions (Page et al. (2008)).

2.2.3.3 Special Purpose Funds as Investment Vehicles

Not only pension funds, private equity funds or hedge funds raise funds and subsequently invest in infrastructure. Also special purpose funds are founded to explicitly invest in infrastructure projects. Most of these funds are so-called stapled funds, which can be listed or unlisted.

This type of infrastructure fund is especially common in Australia and Canada and constitutes one of the main financing tools for new infrastructure projects. The Australian funds, like the well known Macquarie Funds, are mostly stapled securities, creating a non-operating structure.

A stapled, fund structure implies that a trust is installed, which does not operate the infrastructure and is mainly used as a ““pass-through” vehicle for tax purposes” (Davis (2008), p. 2 or Regan, Love, Smith (2013), p. 337). It is founded in addition to a management company, which is a stock company. The management company co-ordinates and invest the trust, distributes the income etc. (Davis (2008), p. 2). The investors can only buy a share of the infrastructure trust in combination with a share of the management company. So the two are “stapled” together and cannot be traded separately. The problem of this stapled structure is that investors can hardly influence governance decisions or control them.

The stapled structure induces possibilities to abuse the power to the disadvantage of the shareholders by reducing their influence: too optimistic re-evaluation of the assets, too high increase of external leverage, distribution of income not justified by returns, purchase of overpriced assets and too high fees to the managing company within an intransparent system. Only external debt by banks imposes some kind of external control (Davis (2008), p. 4pp).

2.2.3.4 Governments

Governments are currently and have mostly been the main players within the infrastructure sectors. But in the last years, tight budgets and the disillusion of management and performance of public companies turned towards a trend of private companies investing increasingly in infrastructure (Dailami, Leipziger (1997), p. 6).

But this paragraph does focus on the role governments‘ actions play for private participants in the infrastructure sectors, but not focus on governments constructing, owning, operating and maintaining of infrastructure.

Even though governments might decreasingly construct, own, operate and maintain infrastructure, their support of infrastructure investments is necessary to reduce risks, which are caused by high sunk costs of construction and the lack of possibilities to reuse infrastructure for other means. This is also true with regard to commercial risks, which are related to non-payment of public entities and especially to political and regulatory decisions (Dailami, Leipziger (1997), p. 6).

Governments have different tools to support private investors: explicit guarantees, comfort letters or other insurances. They can stick to contractual obligations like guarantees of the off-take in projects, or guarantee the fuel supply in power projects. The government can reduce currency risks by guaranteeing the convertibility of currencies (which is especially important in developing countries) or give guarantees for cases of new laws and regulations (Dailami, Leipziger (1997), p. 7). Equivalently market and financial risks can be reduced by governmental guarantees, namely e.g. the guarantees of interest rates, exchange rates and debt. In case of market risks the state can guarantee tariff rates or sale numbers as well as revenue guarantees (Dailami, Leipziger (1997), p. 8).

But governments can equally be a risk for investors. Thus an important argument impeding investments in private infrastructure is found in developing countries, the so-called “creeping expropriation”. Creeping expropriation describes the fact that governmental changes, such as in the tax law, import or export regulations, are burdened to the infrastructure investor and thus reduces returns and the overall value of the project (Schnitzer (2002), p. 42).

2.2.4 Structures and Partnerships in Financing Infrastructure

Network industries are capital intensive. So it is especially important to mitigate the risk optimally between partners (Marques, Berg (2011), p. 925). Most often infrastructure is financed via project finance. So in the next chapter, some determinants of project finance and corporate finance are discussed. Often infrastructure projects also involve governments so that so-called public private partnerships (PPPs) are created.

2.2.4.1 Project Finance

According to Hellowell, Vecchi (2012) project finance is defined by the fact that a private consortium raises capital to finance investments in construction and the operation of infrastructure. Equity and debt investments are compensated by cash flows generated by the infrastructure. The cash flows are generated by fees disbursed by the users and additionally or exclusively paid by the public authority (Hellowell, Vecchi (2012), p. 1). Shen-fa and Xiao-ping (2009) define project finance as a "technique for financing long-term funds for large-scale and capital intensive projects" (Shen-fa, Xiao-ping (2009), p. 1757). Etsy and Christov (2002) define project finance to be creating a legally independent project company which is financed with equity from one or more sponsoring firms and non-recourse[10] debt for the purpose of investing in one asset"(Etsy, Christov (2002), p. 2). Further relevant topics included in their definition are "equity from one or more corporate entities known as sponsoring firms for the purpose of financing investment in a single-purpose capital asset" and the assumption of a usually limited life-time of the project (Etsy, Sesia (2010), p. 3).

Esty and Sesia (2010) concentrate on a study in project finance structures. Examples they quote are a pipeline, worth US$ 4 billion, from Chad to Cameroon, a US$ 6

[10] Non-recourse means that the project is financed with no or only limited support from the financier; the loan syndicate therefore bears the business risk.

billion global satellite telecommunications system or a Euro 900 million toll road in Poland (Etsy, Sesia (2010), p. 1). They argue that firms are already used to project financing structures for "industrial projects such as mines, pipelines, and oil fields" (Etsy, Sesia (2010), p. 1) and start to apply these tools to other types of infrastructure.

Project finance is typically used for greenfield projects, which are independent of other projects and show a high complexity, including high risks and massive information asymmetries. The debt financing of the project is usually non-recourse and syndicated. The leading bank usually takes over the role of a project insider especially in the initial screening and the structuring phase. The bank is forced to take over the role of the insider and reduce business risks by reducing information asymmetries because the syndicate bears the business risk, and faces high high leverage (see Kleimeier, Versteeg (2010), p. 51). This structure reduces agency and transaction costs based on the property of the asset that specialized infrastructure cannot be used for other purposes (Sawant (2010), p. 1041).

Hellowell and Vecchi ((2012), p. 1) state that project finance is the most frequently applied financial structure in public-private partnerships. Infrastructure investments typically show a complex risk profile, a long lay-off period and sensitivity to country risk factors. The investments are typically up-front, the assets are highly specific (even so the extent of sunk investments varies in regard to the sectors) and the cash flow streams cover a long payback period (Dailami, Leipziger (1997), p. 2, 4). Equivalently Shen-fa, Xiao-ping ((2009), p. 1757) state that the benefits of project financing are the strong risk diversification and risk isolation. These factors need a high degree of protection, especially in developing countries, because most infrastructure investments cannot easily be replaced or reused, so that usually different types of co-operation models with the government are implemented to share these types of risks ((Dailami, Leipziger (1997), p. 5). An overview of different types of partnerships between the public and the private sector are given in the next chapter.

In contrast corporate finance is more flexible and allows different adjustments which are not possible in project financing, such as the reconfiguration of assets, an altering capital structure or the coinsurance and substitution between different assets of an enterprise (Sawant (2010), p. 1037).

Kleimeier and Versteeg ((2010), p. 49) emphasize the unique contractual structure of project finance which reduces transaction costs. This is based on the fact that project financing imposes transparency. As only one project is financed, there is no lack of information regarding the investment or the capital allocation. Within a corporate financing structure, the capital can be reallocated towards other projects or needs. Insufficient monitoring and the enforcement of corporate governance is not of importance, as well as the inability within the project finance structure to mobilize pool savings to cope with risks which are not sufficiently mitigated (Kleimeier, Versteeg (2010), p. 49 p).

Especially in developing countries, infrastructure project finance has become an important factor to attract foreign capital (Dailami, Leipziger (1997), p. 2).

2.2.4.2 Private Partnerships - PPPs

To finance infrastructure projects different possibilities exist. The most extreme variations are complete governmental provision or complete private provision. But in between these extremes, various combinations are possible, mostly summarized with public private partnership (PPP).

PPPs are the new term for the old construct of risk-sharing-concessions (Stevens, Schieb (2007), p. 31). Australia, the UK, Ireland, Spain, Portugal and the Netherlands mainly adopted PPPs, which are best suited for large projects where infrastructure access can be controlled, e.g. transportation, water and sewage but less in telecommunication (Stevens, Schieb (2007), p. 31, p. 34).

The detailed procedures of how PPPs are implemented vary between countries. A good summary is given for PPPs in Australia, where, according to the Australian Guidelines for PPPs, the public sector specifies the amount of output for the services; private contractors or a consortium of private contractors bid for the contract in a formal and competitive auction; the construction of the asset is financed privately, as well as the delivery of the service, the management of the assets and the services (Commonwealth of Australia 2008).

2.2.4.2.1 Characteristics of PPPs

The major approaches in private participation in infrastructure projects in recent years, public private partnerships (PPP) and private finance initiatives (PFI) as PPPs were used to be called in the United Kindom (Smyth, Edkins (2007), p. 232), allow to transfer the financial burden to private investors, while the government contracts the characteristics of the infrastructure. Private Public Partnerships offer the private sector the opportunity to fund infrastructure projects with a long-term duration (Marques, Berg (2011), p.925).

The financial crisis, following the collapse of Lehman Brothers in 2008, still impacts the space of investments in infrastructure. The volume of PPPs in Europe is still decreasing from 18 billion Euros in 2011 to 11 billion Euro in 2012. (see EPEC (2012) p.1). Additionally there are constraints on the supply side caused by financial sector regulations (e.g. Basel III[11], Solvency II[12]), and bank concerns in terms of long term lending. As infrastructure investments require dedicated teams and access of the teams to monitor the credit risk and infrastructure project investments show severe information asymmetry and the lack of specialists in the assessment of this kind of investment, banks are hesitant to support these investments (Della Croce, Yermo (2013), p. 27p).

PPPs often are financed by project financing or specially designed hybrid financing instruments. Often PPPs are highly leveraged, especially in Australia. Debt finance is based on medium-term loans, covering 6-7 years with refinancing afterwards, or long-term bond issues covering 10-12 years, showing various interest rates and currency combinations (Regan, Love, Smith (2013), p. 337). The credit rating is based

[11]The Basel III stability ratios increase the costs for banks for long term investments as the ratio of equity capital to risk weighted assets have to be increased from 8% in 2013 to 10.5% in 2018. Instead of increasing the equity capital, many banks intend to decrease the risk weighted capital (see Bassanini, Reviglio (2011))

[12]Solvency II establishes a minimum capital requirement for insurance companies, these regulations are likely to be adopted by pension funds as well.

on the characteristics of the PPP deal: the track record, the credit strengths of the consortium and the ability to finish the project. Also state or municipal bonds are involved for financing (Regan, Love, Smith (2013), p. 338). Some PPPs are listed on stock exchanges to raise equity, although most PPPs edit off-market bonds or request debt syndication (Regan, Love, Smith (2013), p. 337).

To facilitate the investment governments create low-risk assets intending to attract additional debt capital into the sector (Hellowell, Veccini (2012), p. 3). Engel, Fischer and Galetovic (2010) summarize the problems of PPPs. The first problem is that PPPs allow off-budget spending and thus are attractive to politicians. In their example only 14% of the 599 PPP projects in the UK in April 2009 were outlined on the governmental balance sheet. Secondly the complexity of the infrastructure projects requires regular renegotiations during construction or operation and are thus without competitors. "It opens the doors to pork-barreling, and the lack of competition and informational asymmetries at such a stage of a project can lead to considerable increases in cost and reductions in service quality"(Henckel, McKibbin (2010), p. 6).

HM Treasury, the UK's economic and finance ministry (2012), summarizes the introduction of the Private Finance Initiative as their aim to provide good quality and maintenance of assets for the taxpayers' money by the participation of the private sector in designing building, financing and operating public infrastructure (HM Treasury (2012), p. 5).

There are also traditional procurement contracts where the government agency carries the costs of providing the services, carries residual operational and life cycle cost risk and delivers the services unless this is contracted to outside managers (Regan, Love, Smith (2013), p. 336).

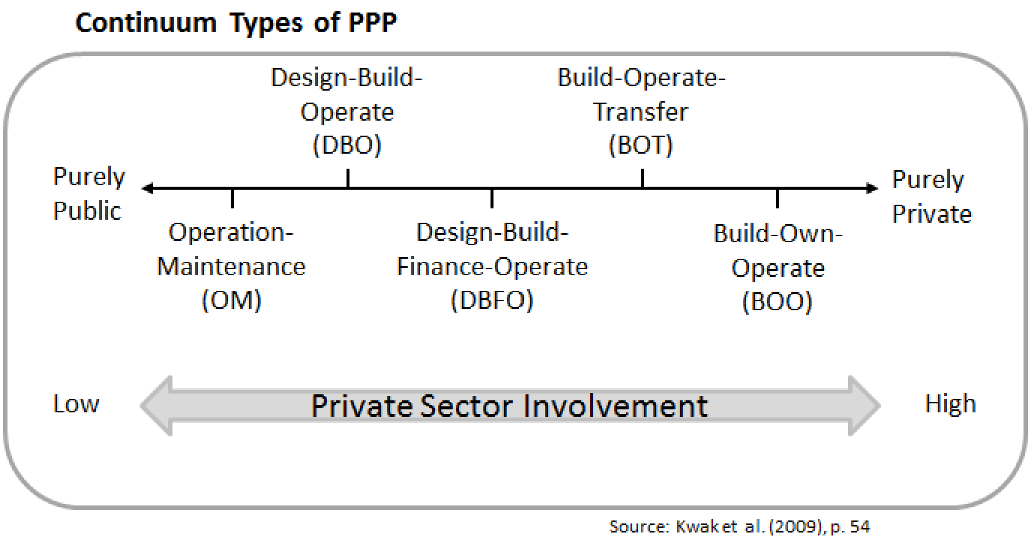


FIGURE 2: Continuum Types of PPP

2.2.4.2.2 Types of PPPs

Different forms of PPPs can be distinguished based on the level of private sector involvement. Regan et al. quote a differentiation introduced in the late 1990s: so-called build-operate-own-transfer (BOOT), build-transfer (BT) or operate-transfer (OT) contracts (Regan, Love, Smith (2013), p. 336). In contrast Kwak et al. (2009) distinguish between purely public and purely private. Between these two extreme types of provision they differentiate between, starting with a low to an increasing private sector involvement: Operating-Maintenance (OM), Design-Build-Operate (DBO), Design-Build-Finance-Operate (DBFO), Build-Operate-Transfer (BOT) and Build-Own-Operate (BOO) (Kwak et al. (2009), p. 54).

For example BOTs are mostly applied in the transport sector. The BOTs are concession schemes in which the private sector finances, develops, operates and, after a contracted period, transfers the asset to the government (see e.g. Walker, Smith (1995)). This highlights the conflict between the private sector, aiming to maximize its profit and the social sector, expecting the maximization of the social welfare. They argue that the pricing strategies of the private sector according to different routes might influence the benefits of the road users. So it is important to regulate the key issues of the project performance and the price of service (see all Subprasom, Chen (2005), p. 3883pp).

The PPPs, based on the individual project characteristics can be differentiated with respect to

- its specific regulations;
- its price control;
- construction cost subsidies;
- extension of the concession period.

Thus, the governments apply different regulatory measures to achieve the relevant political goals regarding profit, social welfare and the quality (Subprasom, Chen (2005), p. 3884)

2.2.4.2.3 Risk Mitigation in PPPs

PPPs involve a risk transfer from the government to the private sector (Henckel, McKibbin (2010), p. 7). Stevens and Schieb (2007), therefore argue that PPPs are the state of the art terminology for the commonly applied construct of risk sharing concessions (Stevens, Schieb (2007), p. 31). The risks transferred to the private investors are risks in construction, financing, operation, maintenance and the conception of the work during the ownership of the concession period. The PPPs cover the full cost of construction. Additionally, they face high penalties when they do not fulfill contract requirements (Stevens, Schieb (2007), p. 34).

So the perspective of the government is that the private contractor carries all the risk of the asset, such as construction risk (including budget and time overruns) as well as delivery risks (e.g. service delivery failure). The main challenge is to find the optimal level of risk transfer for the different risks (Marques, Berg (2011), p. 926):

- Construction risk usually is completely transferred to the private sector to reduce cost overruns and project delays. According to the National Audit Office (2003) in the United Kingdom in 2003, 76% of the privately owned and managed infrastructure projects were on time and 78% on budget compared to the publicly owned and managed projects where 30% were on time and 27% on budget (Marques, Berg (2011), p. 927p).

- Consumption and demand risks - e.g. a parallel bridge or a new competing highway, which is subsidized by the government (Marques, Berg (2011), p. 928), should be borne by the public sector. Renegotiations in case of changes in consumption and demand are one way to distribute this risk from the private owner to the public(Marques, Berg (2011), p. 926). An example for contractual arrangements to cope with this risks is that within the concession period the increase e.g. in tolls has to be at maximum as high as the inflation rate. The expected internal rate of return is around 9.2-17.3%. (Stevens, Schieb (2007), p. 34)
- Other risk factors are market volatility, the vulnerability of infrastructure to mergers and acquisitions, the refinancing risks, especially based on the long term investments cover, changes in exchange rates can be threatening for multinational companies, high credits spreads and rising interest rates (Regan, Love, Smith (2013), p. 332).

The problem is how to cope with risks which cannot be controlled (Marques, Berg (2011), p. 928). One solution is to analyze the risks in detail, following the points highlighted by Marques and Berg (2011):

1. Identification of risks;
2. Classification and allocation of risks;
3. Evaluation of the probability of the risk;
4. Quantification of the risks impact;
5. Delineation of measures of risk minimization (Marques, Berg (2011), p. 926 p).

So when risks are assigned favorably, PPPs can reduce base costs by entitling the private sector to capture residual savings. Public operators and owners do not have incentives (Marques, Berg (2011), p. 926) to produce at minimal cost, as the theoretical chapter on regulation in networks will show. However, when the risk allocation is imperfect or the contracts are inefficient, the private sector can face high costs, failure and even bankruptcy (Marques, Berg (2011), p. 926). In successful PPPs the contractual arrangement implements reduced procurement costs and improved value for money outcomes (Regan, Love, Smith (2013), p. 336). So, based on the different risks mentioned, PPPs are long-term investments, and early-stage patronage errors do not necessarily imply that an infrastructure project is not viable (Regan, Love, Smith (2013), p. 337).

2.3 Challenges for Private Investors in Infrastructure

Although PPPs face several advantages in comparison to project finance of infrastructure construction, several challenges are prevalent for both types.

First, governments and the private sector might have different expectations with regard to the infrastructure. Second, the government might not have a resilient motive or fail to commit to these motives. Third, infrastructure investments involve complex decision making, covering long term periods. Fourth, the legal and regulatory regime can be intransparent or inadequate and thus impose an additional risk on the private sector. Fifth, risk management is the main parameter to exploit the benefits of PPPs or project financed investments, but is also complex in application. The sixth challenge of PPPs or project financed investments is the financing itself. Insufficient capital markets and the lack of long-term financing sources impede private infrastructures investments (see for all Kwak, Chih, Ibbs (2009), p. 51pp, Della Croce and Yermo (2013)). Seventh, PPPs or project financed investments face higher capital costs than the public sector does (Stevens, Schieb (2007), p. 34).

All these challenges directly influence the profitability and the performance of the investments.

Capital costs are an important issue in markets with high investment costs. It might be in the government's interest to finance more infrastructure projects because more projects would be financially feasible for the government in contrast to private investors with higher capital costs and an insufficient capital market. This is the downside of the higher profitability calculation of PPPs or project financed investments faced because of lower project costs and a better performance of staying within the financial and time frame (Stevens, Schieb (2007), p. 34).

The challenge of high capital costs for private investors is discussed e.g. in Australia, because although private investors face higher capital costs than a public owner, the risks are not transferred to the public (Regan, Love, Smith (2013), p. 336). To cope with this problem in the UK the Credits Guarantee Finance was introduced in 2003. This guarantee allows PFIs to use public debt for the financing of infrastructure projects. Thus the cost of capital is reduced and the value for money for the state is improved (Regan, Love, Smith (2013), p. 340). Cheaper public capital also increases the number of projects feasible and profitable for private investors.

For a government each investment project with a social rate of return at least equal to the governmental cost of capital is economically viable and socially desirable (Peree, Välilä (2005), p. 5). So it is obvious that public and private goods are imperfect substitutes and thus a completely private provision of infrastructure prevents the investment in socially desirable projects (Peree, Välilä (2005), p. 6). In contrast excessive governmental investments in infrastructure might discriminate private investments, which do show efficiency gains (Peree, Välilä (2005), p. 9). Also, water and waste-water infrastructure with its long durability of up to 100 years is still mostly owned by the public, as revenues are unlikely to cover costs (Marques, Berg (2010), p. 341).

Regulatory interventions of governments, high risks and comparable high credit costs (in contrast to competing companies owned by government) lead to the question

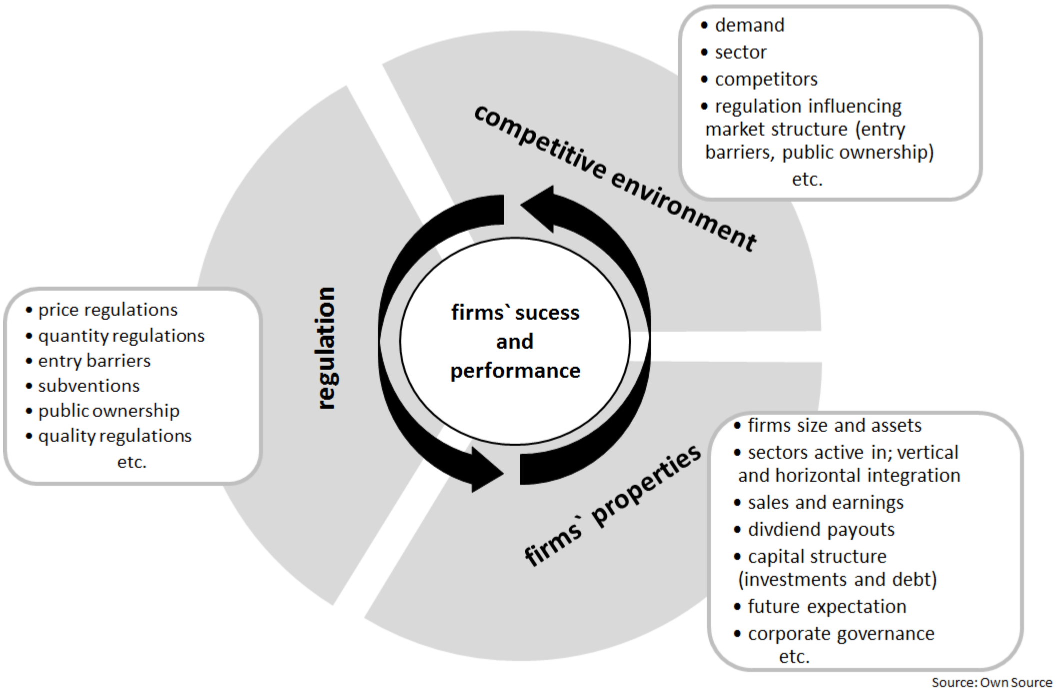


Figure 3: Challenging Factors for Profitability of Private Infrastructure Investments

whether private investments in infrastructure are reasonable and profitable. The relationships are displayed in figure 3.

While chapter 3 on the economic theory of infrastructure only focuses on the term "earnings" and the theoretical construct of sales minus costs, this paragraph gives some insight on performance indicators to be used in the empirical part. Therefore accounting and financial market variables are introduced, although 'the accounting variables are prone to creative accounting and earnings manipulation (see e.g. Tirole (2006), p. 299).

Unfortunately the terms "performance" and "performance measurement" are applied very differently (see e.g. Becker (1998), p. 43ff). Performance measurement within a firm is usually based on a set of key indicators, integrated in a system. Examples are the Balanced Scorecard, the Performance Pyramid, or the European Foundation for Quality management (EFQM) (see e.g Grüning (2002), Gleich (2001)).

In this thesis only key indicators relevant for shareholders are introduced. Gleich ((2001), p. 297) identified in a survey several important financial key indicators for shareholders: earnings before interest and taxes (EBIT); net profit (after interest and taxes); the operating income; cash flows; sales; return on equity (ROE); return on assets (ROA); sales growth; capital structure; liquidity and costs. All these indicators highlight the current and past development of the firm. The indicators return on assets (ROA) is chosen in the empirical part of the thesis to assess the performance of the firms.

Capital market theory assumes that the market participants all have homogeneous expectations on risk and return of an investment, so that the market price of the investment reassembles the future value of the investment including the risk (see. e.g. Wöhe, Döring (2000)). While Rothballer and Kaserer (2012) evaluate the systematic risk (β) with the market portfolio, the empirical part of this thesis will concentrate on the question whether the current and the future performance of the firm is influenced by the property of the infrastructure, the network type or other variables highlighted in chapter 3.

So ROA assesses the current performance of the firm while Tobin's Q assesses the market valuation of the firm in relation to its net assets.

- Return on Assets
  Return on assets is calculated by dividing earnings before interest and taxes (EBIT) with the total assets($ROA_{i,t} = EBIT_{i,t}/TotalAssets_{i,t}$) (See. e.g. Preißler, p.104). EBIT benefits from the fact that taxes and interest rates are not subtracted. As the thesis uses an international panel set, the different tax rates and interest rates might impose to distortions. ROA is used as a proxy of the profitability of a firm (Grullon, Michaely (2007)) and can be seen as a measurement of operating performance (Klapper, Love (2004), p. 709)). An negative ROA requests more capital based on bad performance in the past (Beiner et. al (2004), p. 10).

This performance measurement is based on accounting data. The ratio implies whether the returns in relationship to assets are different in the different types of infrastructure. ROA can be assumed to show whether firms have excessive earnings.

The second variable, Tobin's Q allows an assessment of market valuation of the firm in correlation to its net assets.

- Tobin's Q

  Tobin introduced the variable q, today indicated as Tobin's Q, in 1963 (see e.g. Lindenberg, Ross (1981), p. 2). Tobin created the variable to determine whether firms have an incentive to invest or not, based on cost and capital investments. Therefore the relationship of the firm's market value is related to its net asset value. The market capitalization is the total market value of the firm, calculated as the product of the year end price and the number of shares outstanding. The market is assumed to internalize the expectations of the firm's development. Thus the better the market expects the firm to develop, the higher the demand for the firm's shares is, the higher is the price, the higher is the market value to net assets. Other researcher relate the ratio to questions of monopoly power and the influence of regulation. This relation can be made as the share price not only mirrors the current value of the assets but also incorporates the firm's competitive environment, possible market entry and the significance of regulation to the firm's performance (see e.g. Lindenberg, Ross (1981), Doidge et al. (2004), La Porta et al. (1999)).

  So the idea of Tobin's Q is to assess the firm's competitive power. When Tobin's Q, the market value related to net assets, exceeds one, it is assumed that the market expects the company to have high market power and potential and could invest more. A Tobin's Q smaller than one indicates that the firm has more assets than the market expects to be profitable. The market values the firm lower than the value of selling the firm's assets.

  As Tobin's Q dates back until 1963, different methods of calculation can be found in the literature. In 1994 Perfect and Wiles tested different constructions of Tobin's Q. They found that Tobin's Q based on book values differs consistently from the other estimators calculated on base of the Lindenberg and Ross method or a simplified version of the method. The Lindenberg and Ross method uses replacement cost estimates of firm's physical assets and market value estimates of firm's debt (see Lindenberg, Ross (1981) or Perfect, Wiles (1994), p. 316). As both information is complicated to gather and construct so that I follow the calculation published by La Porta et al. ((1999), p. 19) or Doidge et al. ((2004), p. 216) to calculate Tobin's Q as follows: $TQ_{i,t} = TotalAssets_{i,t} - BookValueOfEquity_{i,t} + MarketValueOfEquity_{i,t}/TotalAssets_{i,t}$.

So these two variables are introduced to assess current and future performance of firms active in infrastructure. They will be used to assess the hypotheses, which will be developed in chapter 3 on economic theory and be examined in the chapter 5 empirically.

Investors are interested to gain returns, so Tirole emphasizes ((2006), p. 29pp, 283) three topics to be differentiated:

- the corporate governance of the firm;
- the financial structure;
- the competitive environment.

While this chapter has shown that several important properties for infrastructure might exist, such as stable long term cash flows combined with a low risk of deficits, the competitive environment of infrastructure is not defined in detail. So in the next chapter the theoretical properties of infrastructure are discussed and connected to some questions of corporate governance.

Chapter 3

Definition of Infrastructure and Relevant Economic Theories

The last chapter highlighted several important facts. First, infrastructure is important for economic growth and productivity. Second, the demand for adequate and reliable infrastructure continues to grow. Third, governments are not able to cover the increased investment needs in infrastructure. Fourth, private investors started to construct, own and operate infrastructure, facing several challenges in order to be profitable, using different types of involvements like PPPs or project financing. And fifth, and most important, while a vast amount of different strands of research focus on infrastructure, its imperative for economic growth, its costs, and the financing gap, as well as research on private participation, no definition for infrastructure was agreed on yet. Thus, no proper theoretical concept for infrastructure was developed, to assess whether private investments can be profitable and how the market has to be structured to allow profitable investments.

This chapter will propose a definition for infrastructure. Following the definition several relevant economic theories are introduced to apply them to the different identified sectors and to develop the hypotheses of factors influencing the profitability of the firms to be tested in the empirical part. The definition was developed on the Center for Entrepreneurial Finance (CEFS) by Florian Bitsch and me. He used

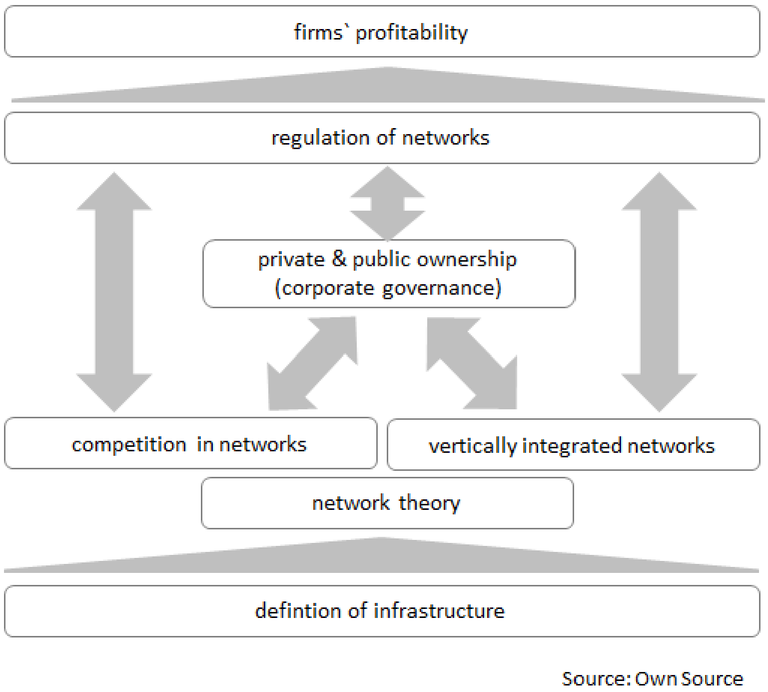


FIGURE 4: Economic Theories and Infrastructure

the definition equally in Bitsch (2012). Nevertheless we both developed different conclusions based on this definition.

The economic theories of this chapter are displayed in figurefig theories. Network theory is the basis for the definition and leads directly to theory of competition and problems of monopolistic structures within networks. Equally vertical integration of infrastructure is an imperative topic, caused by the property of networks and influences the competitive environment. Prevalent monopolistic structures are the reason why until the 1980s infrastructure ownership and operation was seen to be a governmental task. Thus the privatization of construction, ownership and operation induced several problems. First, within the privatized firms in monopolistic structures corporate governance mechanisms are hard to be implemented based on missing benchmarks. Additionally, monopolistic firms do have the incentive to create excessive earnings, which might cause socially suboptimal situations, threatening growth and profitability of the country's economy. Thus regulation, the last theory highlighted in this chapter, is of importance to understand the theoretical framework private infrastructure faces when trying to be profitable.

3.1 A Definition of Infrastructure

In this paper I distinguish between two different categories of infrastructure: economic and social infrastructure. This differentiation is quite common in economic literature (see e.g. Buchner et. al. 2008).

Economic infrastructure as a physical network with properties of natural monopolies includes the sectors energy, including electricity, oil and gas; telecommunication, transport, water and waste-water.

Social infrastructure follows the idea of covering a specific area. This could be backed by Hotelling's spatial competition model for supermarkets in industrial theory (see e.g. Tirole (1988)). The topic of social infrastructure and financial infrastructure will not be the topic of this paper. In the following, I use the term "infrastructure" for economic infrastructure.

Definition of economic infrastructure:

- Economic infrastructure in this thesis is defined as physical network, composed of physical nodes and edges. On the basis of this networks infrastructure services are supplied.
- Network theory implies indirect and direct external effects within the networks, affecting demand and supply.
- Physical nodes and edges imply economies of scale and scope. This, in turn, implies, that competition in infrastructure sectors does not necessarily exist or is feasible.

The theoretical argumentation and its consequences for these relationships and characteristics are given in the rest of this chapter. The definition was developed on the Center for Entrepreneurial Finance (CEFS) by Florian Bitsch and me. He used the definition equally in Bitsch ((2012), p. 23pp).

The proposed definition of infrastructure offers the opportunity to identify different dimensions of infrastructure:

- different parts of networks: nodes and edges,
- different types of networks with different properties: directed and undirected networks and
- the network itself and services based on these networks.

It is important to discuss infrastructure, its different parts and its inherent economic characteristics in detail and separately. For example, it is self-evident that there can be competition in offering telecommunication services, in contrast to two competing highways between two cities.

Being able to differentiate between nodes, root nodes, end nodes, edges, services and goods provided within a network creates a taxonomy which forms the basis for the detailed empirical analysis.

The taxonomy used in this thesis is displayed in Table 2. The sectors in focus are telecommunication, transport, energy and water. Each of these sectors is broken down into several sub-sectors. Telecommunication includes the sub-sectors landline, mobile and broadcast; transport contains the sub-sectors rail-, road-, air- and water transport; energy includes electricity as well as oil and gas, and the sector water is differentiated into freshwater and waste-water. Each of these sub-sectors consists of edges and nodes and has special adjunct services the sub-sector provides.

TABLE 2: Taxonomy of the Definition of Infrastructure **Sector**

Subsector	**Network parts**	**Services**	
tele-communication	landline	landline network, joints, receivers	transmission of data
	mobile	mobile towers, mobile phones	transmission of data
	broadcast	satellite, broadcaster, TV-receiver, TVs	transmission of data
transport	rail	stations, tracks, control system	transport of goods and passengers
	road	streets, parking areas	transport of goods and passengers
	air	airports, control system	transport of goods and passengers

Table 2: Taxonomy of the working definition of infrastructure (continued)

Sector	**Subsector**	**Network parts**	**Services**
	water	ports, water streets	transport of goods and passengers
energy	electricity	power plants, joints, transmission line, plug socket	generation and transport of electricity
	oil	oil rig, pipeline, storage	exploitation, generation and processing and transport of oil
	gas	gas rig, pipeline, storage	exploitation, generation and processing and transport of gas
water	fresh water	fresh water side (well), pipeline	fresh water exploitation, transport of water
	waste water	waste water recycling, pipeline	transport of waste water, treatment of waste water

The taxonomy allows the differentiation between sectors, sub-sectors, nodes, edges and services. It provides a tool for discussing different parts of infrastructure based on economic determinants.

Defining economic infrastructure as physical networks so far is rarely applied. Egert et al. e.g. use the definition as a supporting construct, in their study on"Infrastructure and Growth: Empirical Evidence" (Egert, Kozluk and Sutherland, 2009), but they do not develop an economic interpretation of the characteristics. Equally to the approach of this paper, Growitsch and Wein ((2004), p. 21pp) apply a similar systematic to infrastructure sectors but do not create a definition applicable to other sectors. Economides (1996) and Economides and White (1994) developed the economics of networks, the theoretical basis for the argumentation of the thesis and applied them to the networks of telecommunication and transport but did not apply the theory to networks in general.

3.2 Networks and Network Theory

Network theory is the basis of the definition of infrastructure introduced here. The economic properties I present in the first part of this chapter combined with the properties of monopolistic market structures described in the second part of this chapter are the theoretical basis for the empirical analysis of listed infrastructure firms in chapter 5 of this thesis.

Therefore, I will first give an overview and examples which sectors and dependencies in markets led to the development of the economic network theory.

The specific terminology of networks will be discussed within the theory of relevant topics of standards, compatibility and complementarity as well as lock-in and switching costs, which directly affect network effects and thus the firms' performance. An often cited example to illustrate the topic of network effects is telecommunication. Buying and using a telephone is only useful if at least one other person owns and uses a telephone. The more people own and use a telephone, creating an increasing network, the more valuable the telephone is for its owner, connecting him with an increasing number of people. Owning a telephone without having the opportunity to communicate with another person makes the telephone worthless; a network does not exist (see for network effects e.g. Allan (1988), or Cambini, Valetti (2008)).

Then I will focus on the network externalities - so called network effects. Network effects, as mentioned in the telephone example above, are external effects which describe the influence on a consumer's decision to buy a network product and thus the value of the good, depending on the number of network members. Thus networks are the more valuable the more participants use the network. Aside from these positive network effects, negative network effects can be found, which mostly result from congestion. The effects of congestion are based on too many participants within the network, with a specific hurdle for problems of congestion, depending on the existing network and demands. Beyond this hurdle, every additional user leads to decreasing utility in terms of quality or accessibility. Examples of this kind of problem are traffic jams or the failure of mobile telecommunication systems during big local events. But up to this point every additional user increases the value of the network for the existing users. For example, the more people own a car and travel, the more gas stations will be built and operated, and the greater the variety of cars the user can choose from, the cheaper the car gets, and the more roads are built to reach new destinations (see e.g. Economides (1996)). All these effects depend on standardized parts and inputs. As I will show in the detailed analyses of network effects, this is a so-called indirect network effect.

Two different types of networks can be distinguished: directed and undirected networks. In the last part of this chapter, I will combine the economic properties of networks and, following a paper by Economides (1996), elaborate on the differences between directed and undirected networks. These distinctions are important for firms active in infrastructure sectors.

3.2.1 Theory of Networks

This definition of infrastructure is based on the properties of network theory and the fact that I only consider physical networks, built up of nodes and edges.

Networks can be described as nodes that are connected with links. Network theory includes infrastructure and its physical networks as well as vertically integrated industries like software industries and vertically integrated supplier relationships (see e.g. Economides and White (1994), p. 654p).

A network principally consists of edges and nodes and flows between the nodes. thereforee, network theory is based on graph theory. Graph theory is a discipline in mathematics and is prevalent today in many different academic fields. In electrical engineering, graph theory is of importance in topics discussing electric flows. In computer sciences, network theory is the foundation connecting hardware and software and communication networks in companies, including computer terminals, input- and output devices (see Katz, Shapiro (1985), p. 424). ATM networks (automated teller machine or cash machine) are another often cited example in this research area (see e.g. Economides, White (1994), p. 653, or Farell and Saloner (1985), p. 70).

Harary ((1959), p. 387pp) was the first economist to develop social network theory in 1959. In psychology and sociology, networks and networking are the cornerstones of information and communication. Social networking via Facebook or the German based expert network Xing are said to be essential for personal and professional development.

Social network theory also leads to new developments in management. A continuum of single firms was the old standard, followed by co-operating networks, and finally created virtual companies (a summary can be found in Parkhe et al. (2006), p. 560). Mariñoso,(2001), in the context of co-operating and virtual companies describes so-called system goods. System goods are goods which are bought sequentially (Mariñoso,(2001), p. 291) and thus have properties of compatibility and lock-in (Mariñoso,(2001), p. 293), properties equivalently found in physical networks.

Aside from these social types of networks, vertically related industries are associated with network theory. As Economides and White ((1994), p. 654) put it: "[...] a number of authors who have written about 'network externalities' identify these externalities with vertically related industries". So network theory and networks are often not describing the same objects and are mostly not differentiated clearly.

One can cite the discussion of network theory in vertically related industries of the antitrust case US versus Microsoft in 2001. This case was based on the fact that Microsoft bundled their internet browser, the Internet Explorer, with the widely used operating system Windows and thus prevented competition with other internet browser such as the Netscape Navigator, which had to be purchased or at least downloaded. The antitrust case was an attempt to introduce competition in the market for browsers and prevent exploitation within a network system (see Fudenberg, Tirole (2000)).

So the literature on networks often cites topics of different industries like hardware-software networks and issues of compatibility or the increase of utility for the participants based on network size. Although most infrastructure systems are based on a network structure, this property is seldom discussed in detail. Nagurney (2002) uses a definition of networks similar to the one developed in this thesis but defines transported goods and services and other flows as inherent parts of the networks.

Network theory often also includes topics of vertical integration. But this is based on the fact that vertical integration is a main feature of networks, for example the oil and gas industry with its differentiation in up-stream (exploration), mid-stream (transportation, storage and marketing) and down-stream (refining, processing and purifying raw natural gas, as well as marketing and distribution) is typical for properties of vertical integration.

In contrast, production systems with complementary goods (system goods) need specific standards to be compatible, such as in the automotive industry, where the supply chains do not rely on specific physical networks but use the existing economic infrastructure networks to manufacture cars, which are usually assembled worldwide. But the production system itself has properties of network systems and vertical integration. A reason for this can be seen in the use of the term "network", which refers to physical networks as well as to production networks or social networks, thus mixing up concepts and properties. This paper attempts to shed some light on the differentiation of the different topics.

Developing a taxonomy for infrastructure and applying the theory of networks to the different sectors of infrastructure necessitates a survey of the theory of networks. In the next paragraph, I will highlight the most important concepts of network structure, networks and their interrelation.

3.2.2 Structure of Networks

Typically a network consists of nodes and connecting edges or, as Economides ((1996), p. 674) puts it, "networks are composed of links that connect nodes". Harary (1959) explains in his paper "Graph Theoretic Methods in the Management Sciences" that a graph consists of points and lines (Haray (1959), p. 388). Thus, network theory is based on graph theory.

Two types of networks can be differentiated: one-way and two-way networks (Economides and White,(1994) p. 651). Harary ((1959), p. 388) calls the one-way networks directed graphs, consisting of directed lines. In contrast he speaks of undirected

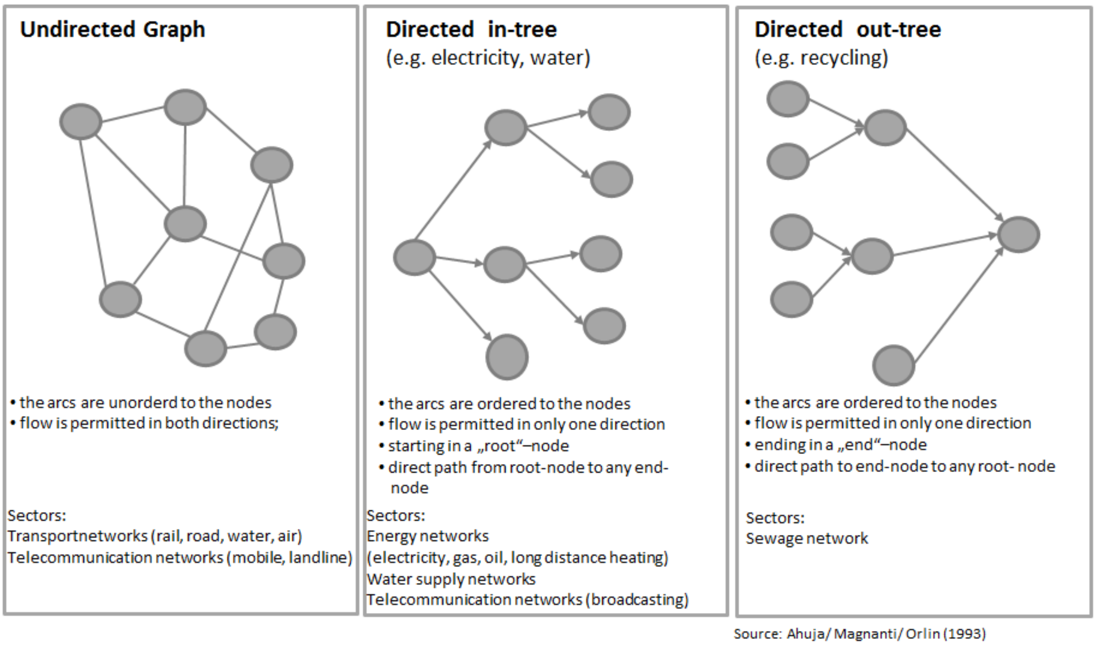


FIGURE 5: Types of Networks

graphs for two-way networks (Harary (1959), p. 389). In this work, I will use the terms directed and undirected networks; directed networks are one-way networks, and undirected networks are so-called two-way networks. In undirected networks, the good can be transported in both directions. The most prominent and best researched example for undirected networks are telecommunication networks. To a smaller extent, the research literature focuses on transportation networks.

Figure 5 shows directed and undirected networks and their sectoral structures in infrastructure, based on Ahuja, Magnanti and Orlin, 1993.

Typical one-way networks are water supply or electricity networks. From a root node, where the product is created, the good is transported to several switches until consumed in an end node. The one-way network can also be differentiated in in-tree and out-tree networks. In infrastructure, the only out-tree-network is a waste-water network, where each root node is connected toward one end node.

Three different ways to calculate the value of the network can be found in the literature. One strand focuses on the overall value created by the existence of the network, for example for productivity or economic growth; the other strand concentrates on the value the network creates for the single consumer. Swann for example describes the example of a broadcast network. The value of the network is dependent on the size of the audience (Swann (2002), p. 418). The value created for the individual consumer is also described as the individual utility increasing with the participation of an additional individual as prevalent in telecommunication networks. The third type of utility is based on the group forming effect of networks (Swann (2002), p. 418) as one can imagine in informal insurance networks. The more participants are in the network, the better is the chance of support in the case of a severe loss (see e.g. Bloch, Genicot, Ray (2008)).

3.2.3 Standards, Compatibility and Complementarity

Standards, compatibility and complementarity are the most important properties of networks and thus intensively researched. Standards lead to compatibility for example a standard for frequencies for mobile phones make the phones interchangeable between different networks with the same standards. Compatible phones are complements to the networks[1].

Trains can only be used on different routes if the gauges of the tracks are identical. The same is true for electricity. Different intensities of current can destroy end-services, different plugs create the necessity to buy adapters when traveling between the US and Europe. The European Commission has passed a law for adapters for mobile phones, so that all mobile phones have to use interchangeable compatible adapters for all types of mobiles (EU, M/455). Regulation in this network with complementary goods decreases negative network effects by the reduction of electronic waste and increases the consumers' utility by a standardized charger.

Standardization thus increases variability and compatibility of network products. Economides and White (1994) show that compatible products are also complementary: a video game needs a compatible station, programs designed for being used on a MAC iOS cannot be installed and used on computers having a Linux operating system or Windows (Katz, Shapiro (1985), p. 81).

[1]This is based on the theoretical literature developed by Economides (1996)

Standards and compatibility play an important role in networks regarding the size of the network. This is called the bandwagon effect: The technology with the largest existing base is increasingly attractive to other users (Suarez (2005), p. 710), and all user follow to install this standard. Thus, as Farell and Saloner argue, large firms are less dependent on whether customers switch, but they have considerable influence on whether new standards are accepted in the market (Farell and Saloner (1985), p. 71 pp).

But Farell and Saloner, 1985, also point out that standardization does not only have social benefits but may also impose costs based on decreased variety. They quote the example of QWERTY the standard for keyboards. This standard was optimal when mechanical typewrites had to be prevented from disabling each other and thus often used combinations of letters have to be distanced from each other (Farell and Saloner (1985), p. 71). Today QWERTY is inferior for typing with electronic keyboards, because other, more economic collocations of letters would accelerate typing. This effect is called excess inertia. It shows that switching is a slow procedure and a critical mass in network systems is necessary.

But Farell and Saloner ((1985), p. 70) find that "Many goods are 'compatible' or 'standardized' in the sense that different manufactures provide more interchangeability than it is logically necessary". They describe the fact that cable programs can be received by the same set and telephone subscriber can talk to people who have subscribed to another company (Farell, Saloner (1985), p. 70). One can argue that companies also take the incentive of governments into account to introduce regulations in favor of standardization, especially in economically relevant networks. An example here is telecommunication in the US, when subscribers to different telephone companies were not able to communicate with each other, so that businesses were forced to subscribe to several telephone companies to be accessible to all consumers[2].

Thus standards increase compatibility and the value for existing consumers in network industries where goods are complementary. Often regulation is implemented to

[2]This is based on the theoretical literature developed by Economides, 1996.

introduce standards, especially when fragmented competition leads to unsatisfactory market outcomes.

3.2.4 Lock-In and Switching Costs

Lock-in and switching costs describe the fact that companies have the incentive to lock their customer into their system (Shy (2001), p. 5).

Switching between providers or standards is often lagged, based on two different structural types of lock-in. First, contracts can force consumers to stick to a specific provider and prevent them from switching to a cheaper or better provider within the contracted period.

The second type, technological lock-in, is more severe, especially when the goods are durable and force consumers to stick to one technology. Technological lock-ins can lead to circumstances where complementary goods are incompatible, so it is cheaper to stick to an old technology than to replace all compatible goods, e.g. the QWERTY keyboard standard. This is especially severe in industries where high investments are imposed by switching the system for example switching the gauge width for all tracks and trains.

But lock-in is also a strategic tool for companies to prevent their customers from switching to another supplier.

Switching costs can be introduced easily into networks. The first attempt is based on the property of complementarity, which imposes costs when switching to another provider because, to be able to accept the offer, completely new products have to be purchased. Free miles or bonus miles collected by airline passengers have to be interpreted similarly. When switching the company, all previously collected miles become invalid and new miles have to be collected to achieve the same privileges the passenger had with the old company.

Another lock-in prevalent in telecommunication markets are long-term contracts, which prevent customers from switching to a new provider, as well as the fact that one gets a new telephone number when switching.

The effective variation is again the example of the US telecommunications sector. Several telecommunication companies were competing for customers and prevented their competitors from accessing their networks. Thus, in order to be contactable for any possible customer, a business had to have a contract with every telecommunications company, with specific numbers, telephones and tariffs (Vogelsang (2003), p. 831). Here it was not possible to switch between separately installed networks.

Switching cost are the costs one has to pay when switching to another provider or another technology. Shapiro and Varian, 1999, extend the list of switching costs in a detailed summary to include training, learning, search and loyalty costs, associated with switching the provider or the system.

3.2.5 Network Externalities

Two different types of network externalities can be described. Direct network effects and indirect network effects, which can be either positive or negative.

Both types of network effects have in common that the number of users in the network influences the value for the consumer. Koski, Kretschmer ((2004), p. 5, following Littlechild (1975) and Rohlfs (1974)) describe them as "demand-side economies of scale" as they have the same properties as economies of scale on the supply side.

Direct network externalities are externalities that are derived directly from an increase in participants in the network. Internet with no other users apart from oneself is nothing but a personal computer. The increased utility is based on the fact that other people share content. Another example is transportation infrastructure. Owning a car or a plane has a higher utility if there is at least one destination to access. Direct network externalities, according to Economides and White ((1994), p. 652), create a new good for each consumer when new consumers participate. This is consistent with the definition used in their article where nodes are equivalent to consumers. In the case of transport, a new house connected with a new road can be associated with a new consumer and thus introduces a new product - traveling to the new consumer's house. In the case of airports or train stations etc. new products are created, but airports and train stations cannot be associated with new consumers.

Swann (2002), refers to Metcalfe's Law to determine the overall value of direct telecommunication network effects: "when there are n users in the network, the number of pairwise conversations is ${}_nC_2 = n*(n-1)/2$. If each of these conversations is of equal value, and of value to caller and receiver alike, then the total value is proportional to n(n-1), or for large n, proportional to n^2 (Swann (2002), p. 418). But Swann also exposes critical findings that not every additional user imposes the same utility to the existing users. There is empirical research showing that consumer entering the network later add less utility to the network and that the composition of the network is important for the outcome (Swann (2002), p. 419). Since the value of a network is not part of the thesis, I will spare the discussion on these topic of research.

Indirect network effects, according to Shapiro and Katz ((1985), p. 424), are either based on a greater variety accessible to consumers, or increased experience with the product. In addition they quote scale effects as indirect network effects. Owning a plane is not affordable for most people. Building a road between Munich and Berlin for oneself is equally not affordable. thereforee people have to cooperate to achieve their goal of traveling in a car between Munich and Berlin or flying by plane. The more people want to participate, the cheaper it will be for the individual person. Thus, roads as well as airports are built by the government and paid by taxes. Planes are bought by airlines and the seats on one journey, the transport services, are sold to the consumers. The more airports exist, the more people are willing to travel, and the cheaper planes get. And the more roads are built, the more consumers are interested in owning a car and traveling between different destinations. The same is true for energy such as electricity, gas and oil. All these effects are based on indirect network effects; they connect a huge pool of users, and not one consumer but all face the costs for the power plant, the pipelines, the streets and so on. The more consumers take part, the cheaper the service of the network gets for the individual user and the more interesting it is to participate in this network. Koski and Kretschmer ((2004), p. 5) also cite the availability of complementary goods as an indirect network effect with the number of consumer increasing.

Matutes and Regibeau ((1996), p. 186) summarize indirect network benefits arising from "improvement in the supply of complementary inputs: An increase in sales of a given product can result in lower prices, better quality and/or greater variety for the goods or services required for the product to be useful." Economides and White ((1994), p. 654) call them "inter-product-network externalities" and explain that this variety creates products or product bundles closer to the consumers ideal. Swann (2002), refers to Sarnoffs Law to describe indirect network effects: "if the aggregate value is proportional to n, then individual utility in a broadcast network is a constant (independent of n) except in as much as a popular broadcaster is better resourced, and thereforee able to offer higher quality content" (Swann (2002) p. 418).

So two types of indirect network effects can be differentiated:

1. indirect network effects based on economies of scale and
2. indirect network effects based on complementary parts.

These indirect network effects also explain why infrastructure was assumed to be a public good for a long time. In contrast to Torrisi, (2010) I argue that infrastructure is not a public good, as public goods are goods where it is not possible to exclude a user and where there is no rivalry in using it.

3.2.6 Negative Network Effects

In this short chapter I will give an insight in the economic network definition as I have put it and the question whether they are private or public goods.

Different Types of Goods

	excludable	non excludable
rivalrous	private good	common good
non rivalrous	club good	public good

Source: Own illustration based e.g. on McNutt (1999), p.931

FIGURE 6: Public and Private Goods

Excludability in economic networks is prevalent: toll stations on highways exclude people who are not willing to pay the toll; the TÜV in Germany excludes cars from traffic when the car does not fulfill the safety regulations; one has to have a contract or prepaid credit to access the telephone networks; electricity and water can be shut off when the bills are not paid in time. The same is true for the service provider using the infrastructure to offer the specific good: to use a water pipeline infrastructure, a contract has to be made and an access point installed. Therefore, economic infrastructure networks are excludable.

More complicated is the question regarding rivalry in consumption. Obviously, a glass of fresh-water can only be consumed by one person, electricity used for television cannot light the lamp in the next household, oil and gas are burnt for energy. So in these services exists rivalry in consumption.

In broadcasting, however, there is no rivalry in consumption. Whether I am talking to two or three people, broadcasting a show to one or 1,000 people does not matter.

But these are the goods transported and made available by the networks.

The remaining question is whether the physical network itself has a rivalry in consumption a question of time and capacity. So, at the moment, a water pipeline transports water from company Y to household X and uses the capacity of this pipeline completely; no water can be transported from company A to household B. But, when the water transfer from Y to X is over, company A can transport its

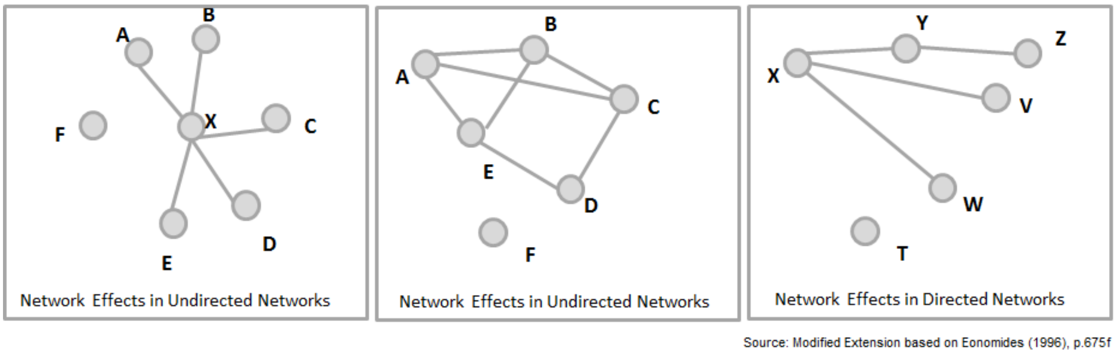


FIGURE 7: Network Effects

water to household B. This is true for all infrastructure networks in this working definition. I will show later, in the chapters of the sector analyses, that problems of capacity and congestion are prevalent in all types of networks. So there is rivalry in the use of the network.

3.2.7 Directed and Undirected Networks

Economides and White (1994) developed in their paper the distinction between network effects in directed and in undirected networks. This paragraph will follow the logic of their paper and thus display the importance of that differentiation.

As described in Chapter 2.6.2, directed networks are networks which begin in a starting node and are directed towards an end node. One can differentiate between directed in-tree and directed out-tree networks. Directed in-tree networks start in exactly one node and end in several nodes; directed out-tree networks start in a bunch of nodes and end in one node, their flow is directed (see e.g. Ahuja, Magnanti and Orlin (1993)).

Undirected networks do not have a specific direction of its flow. The flow is undirected, a path can usually be used in both directions. Transportation networks and communication networks are typically undirected networks, with the exception of broadcasting networks, which is a directed in-tree network.

The research of Economides and White (1994) shows that directed networks have only indirect network effects, whereas undirected networks have direct and indirect network effects.

Thus in undirected networks like telecommunication or transport any new consumer creates a new good. For example, in Figure 4, exhibit 1: Adding the node F to the network adds for consumer A to the existing goods “AXB”, “AXC”, “AXD”, “AXE” the newly created good “AXF”. This schematic is identical for all consumers “A”, “B”, “C”, “D”, “E”, whereas for “F” the whole network is accessible. Economides and White (1994) assume that the nodes “A”, “B”, “C”, “D”, “E” and “F” are identical to consumers, assuming that each of them is a telephone and “X” the switching operator. Other researchers, e.g. Swann (2002) assumes that not each additional node increases the value of the network equally.

Applying this systematic, developed by Economides, to transport infrastructure the dependencies can be displayed like in figure 4 exhibit 2. Assuming that “A”, “B”, “C”, “D”, “E” are existing railway stations, then there are seven direct combinations of routes and several more with a stopover. The integration of a new railway station “F” now creates for all existing stations new traveling possibilities: Including “F” with only one edge to “D” creates one additional direct combination more and for all participants in the network with stopovers the possibility to travel to F. Thus including “F” increases the opportunities for every traveler in this network located at any station. The overall value will be determined by the number of edges which connect the new node and the edges already connecting the existing nodes.

In contrast to that one can see directed networks as displayed in figure 4, exhibit 3. This can for example be seen as an energy network. Including “T” as new end node increases the value of the network for consumer “T” he can participate and get oil or gas, but the other consumers are not directly affected. Of course, indirect effects like congestion, capacity problems or lower quality might appear.

When “T” is introduced as a new start node, this imposes competition between “T” and “X” and thus provides a better or more preferred good for “W”, “V”, or “Z”.

3.3 Competition in Networks

As the last chapters presented, there is rivalry in consumption; consumers can be excluded; different types of networks (directed versus undirected networks) show different external effects; lock-in and switching-costs impose special circumstances; all these properties are relevant for companies active in networks.

To develop an argumentation on competition in networks, I give a short insight in the most relevant topics of competition focusing on properties impeding or enhancing natural monopolies and other market distortions such as for example the already mentioned economies of scale within networks. In a second step, I combine these findings with the properties of physical networks and infrastructure and show that some conditions of competitive equilibria are violated. This violation might lower welfare within a country, for example because a monopolist sets high prices and thus sells smaller amounts than in competitive markets.

Microeconomic theory names the best solution in a market for all participants pareto optimal[3]. This solution is based on the assumption that the price of a good equals the cost of producing the last unit (marginal costs). If the producer asks for a higher price, the consumers buy a smaller amount and another competitor has the opportunity to serve the existing consumers and the consumers with a smaller willingness to pay by offering the product cheaper than the incumbent and serve the whole market. Thus everyone has the incentive to offer a product at the lowest possible price; otherwise someone else will serve the whole market[4].

Following standard theory, to satisfy this competitive equilibrium several assumptions have to hold (see e.g. Viscusi, Harrington, Vernon (2005), p. 79).

1. Consumers are perfectly informed about all goods and their prices; all goods are private goods (a private good is a good which can only be consumed by one

[3] A situation is pareto optimal, if there is no way to enhance the position of one participant by worsening the position of another participant and compensating him (normally monetarily) from the improvement of the first participant. This is the welfare optimal outcome.

[4] This is all true under the standard assumption that marginal costs are increasing with the produced amount and average costs falling (For a production function with the output $y = x_/1 = +x_2$ economies of scale exist, when $ay > ax_1 + ax_2$).

person (called rivalry in consumption) and consumers can be easily excluded, e.g. by charging for the service or good, see e.g. the figure in chapter 6).

2. Consumers maximize the value based on their preferences given their budget constraints; producers maximize profits given their production functions and costs.

3. All producers can access identical production processes and input prices and do not face increasing returns to scale. Increasing returns to scale mean that an increase in the input good is followed by a proportionally higher output.

4. All agents are price takers, and there are no externalities. Increasing returns to scale mean that an increase in the input good is followed by a proportionally higher output.

These four assumptions determine the competitive equilibrium, a set of prices that clear the market (see Viscusi, Harrington, Vernon (2005), p. 79). According to microeconomic theory this situation maximizes the welfare in the economy. In the next paragraph, I focus on these assumptions in detail and discuss whether they are satisfied within large physical networks of infrastructure.

3.3.1 Network Goods

With regard to the first assumption, some publications assume that infrastructure networks are no pure private goods but public goods. As shown in chapter 2.4.6, economists distinguish between private goods, public goods, club goods and common goods. The types of goods are differentiated in two dimensions: rivalry in consumption and excludability. It is often wrongly assumed that a good fits neatly into either one of these categories, while there are many goods which lie between the extreme poles of the categories (see e.g., Sharkey (1982), p. 45).

Baumol, Panzar and Willig (1982) show in their analysis that public goods do not necessarily lead to monopolistic structures. Monopolistic structures are solely based on the cost structure of the production function (Baumol, Panzar and Willig (1982),

p. 301). Therefore, the type of good is not important in the discussion of its welfare effects. Furthermore, as will be displayed in the analyses of the different sectors in chapter 4, all types of infrastructure suffer from congestion effects when crossing a certain threshold so that they cannot be defined as pure public goods. Additionally infrastructure is used non-continuously over time, while construction is expensive, so that sharing costs and/or ownership seems economically viable (it is expensive and takes a long time to construct one road from Munich to Berlin, it is not viable to construct parallel ones for each individual)(e.g. Frank (1997), p. 627).

So networks and its supplied services have rivalry in consumption from a specific hurdle on and consumers are excludable. Thus network goods can be seen as club goods.

3.3.2 Maximizing the Performance in Networks

The second assumption states that consumers and producers maximize their budgets and behave economically rational. As behavioral theory shows, agents do not always act rationally and maximize their individual economic value. Fairness, the urge for penalties or false assessments of risk lead to behavior other than expected with the assumption of economic rationality [5]. Another point to mention here is the lack of transparency of costs. Even in the online easily accessible and searchable infrastructure service market of passenger flights, the cost structure often remains non-transparent for the users. Sharing the costs of non-discrete goods (goods which are shared and not consumed by one person only once) imposes another problem, especially when people face different incomes. As Frank (see Frank (1997), p. 622) shows, people have a different willingness to pay for the provision of a shared good. This might lead to smaller amounts being provided due to the fact that some consumers are willing to pay higher prices, so that only the quantity for people with a high willingness to pay is provided, the quantity demanded by the consumers with a smaller willingness to pay is ignored, so that in the end a smaller aggregated amount than necessary is provided.

[5] See for example Kosfeld et al. (2005) for new experimental theories in behavioral economics.

A further distortion to mention here is the so-called X-inefficiency. For most parts of the 20th century infrastructure was provided publicly or protected by law against competition. This prevented the need for the companies to cut costs, improve processes and develop new technologies. This inefficiency is caused by non-existing competition. Thus competition and regulation forcing competition support maximizing agents and competitive outcomes. In networks with governmental actors or complex construction projects maximizing the outcome might be impeded. A more detailed discussion of this topic can be found in the last paragraph of this chapter.

3.3.3 Identical Production and Economies of Scale

The third assumption tackles the core of natural monopolies, based on two arguments. Firstly, technological developments and patents create advantages for companies to their competitors. Thus cost- or product advantages impose a monopolistic position at least in the short term. These advantages nevertheless induce RD incentives in the first place and thus enhance technological development. Because most of these developments are protected by patents, regulation determines the type and the duration of the monopolistic advantage (e.g. Earl (2007)).

Secondly, increasing returns to scale (= economies of scale) have long been assumed to be sufficient to ascertain a natural monopoly (see Sharkey (1982), p. 37). Baumol, Panzar and Willig state that economies of scale have been mistaken as an identifier for natural monopolies, while it is the more complex concept of subadditivity. A cost function, according to Baumol, Panzar and Willig is strictly subadditive, if for all produced outputs at any amount, it is cheaper to be produced by one firm than producing the good or service by any combination of smaller firms (Baumol, Panzar and Willig (1982), p. 17, p. 170). They proved that economies of scale and scope[6] are not sufficient for sustainability. However, cases exist in which economies of scale or scope imply the more complex concept of sustainability (see Baumol, Panzar,

[6]Economies of scope are production advantages in the production of several products, stating that it is cheaper for one firm to produce both or several different products combined instead of several firms producing each product alone or a smaller amount of products.

Willig (1982), p. 22, p. 173). The relevance of these findings will be highlighted in the next sections.

Following Growitsch and Wein (2004), I will assume in the following part of the paper, that economies of scale and scope at least imply oligopolistic or monopolistic structures as it is prevalent in most parts of infrastructure. In chapter three I will determine in detail for each subsector of infrastructure whether it has severe economies of scale.

Intuitively, fixed and sunk costs are the basis for economies of scale. But the concepts of fixed and sunk costs are not unambiguously differentiable (E.g. Tirole (1988), p. 307; Sharkey (1982), p. 37). Fixed costs are costs which are invariant to changes in production. Tirole defines fixed costs as “costs that are independent of the scale of production and are locked-in for some short length of time, which defines the “period”” (Tirole (1988), p. 307). Compared to that sunk costs are specified as costs “that produce a stream of benefits over a long horizon but can never be recouped” (see Tirole (1988), p. 308). Thus the distinction between fixed costs and sunk costs is determined by the time period. In addition, the definition of the market determines if costs are sunk. Sharkey stresses the example of an airplane which can only be used in transport. So the costs are said to be sunk for transport, as there is no other usage. But they are not sunk for the transport route or company, because the plane can easily be sold to another company or used on a different route (see Sharkey (1982), p. 37).

Based on the argumentation that economies of scale and scope impede competition and they are caused by fixed and sunk costs, one can assume, that networks might show at least some non-competitive properties and tend to create oligopolistic or monopolistic markets. So in the next paragraph a short insight in the most influencing theories on monopolies and its history in research are given.

Economists of all times have observed closely single suppliers of goods or services in markets. This is based on the fact that the monopolist faces the opportunity to abuse his market power to offer products or services at a higher price and a smaller amount than in a market with several suppliers. From a public point of view this is especially severe for products and services which enhance economic development and public well-being, such as e.g. infrastructure.

In 1838, Augustin Cournot was the first economist to realize that monopolistic structures reduce social welfare (see Sharkey (1982), p. 13). Ten years later, in 1848, John Stuart Mill was the first economist to speak of natural monopolies. He observed that public utilities exist which cannot be provided in a competitive structure (see Sharkey (1982), p. 14).

In 1982, Baumol, Panzar and Willig published the "Theory of Contestable Markets", which introduced the first taxonomy for an assessment of natural monopolies and is considered to be a "generalization of the theory of competition" (see Spence (1983), p. 981).

While in the standard theory of natural monopoly one assumes the monopolist to set the price and assesses a monopoly by the number of players (one), Baumol, Panzar and Willig give a more detailed view on the topic. They show that it is possible for one player to offer his products at a price equal to marginal costs even though no competitors are on the market. Their taxonomy altered the discussion of monopolies, regulation and privatization. They identified three conditions which have to be satisfied to face competition:

- no subadditivity,
- sustainability,
- contestability

(see Baumol, Panzar, Willig (1982), p. 5; Growitsch, Wein (2004), p. 29; Tirole (1988), p. 307.).

The main argument of the Baumol, Panzar and Willig (1982) theory is the "hit-and-run- argument", based on these three assumptions. It says that if any entrant can just enter the market with no time for the incumbent to adjust prices, the entrant would ask a smaller price than the incumbent and thus serve the whole market at least until the incumbent can adjust the price. Afterwards he can just leave the market and keep his earnings. The incumbent anticipates that and thus serves the market for the optimal competitive price (see Tirole (1988), p. 308 f.; Baumol, Panzar and Willig (1982)).

This generalization is also applicable for cost structures with falling average costs. When average costs are high and marginal costs are comparatively small, a price equal to marginal cost leads to losses. Thus the perfect price would be a Ramsey pricing (Ramsey prices are not a specific price but a price structure for non-linear price discrimination, based on elasticity of supply and demand). Baumol, Panzar and Willig show that even monopolies are bound to earn no more than the normal rate of return on their capital investments. In the contestable market, the monopolist can only earn zero profit and must operate efficiently "if certain conditions on the available set of production techniques and the nature of the market demands are satisfied and, then the Ramsey-optimal prices for the monopoly firm (that is, the prices that maximize consumer welfare, subject to the financial viability of the enterprise) are guaranteed to be sustainable and are therefore guaranteed to effect an equilibrium in a contestable market" (Baumol, Panzar and Willig (1982), p. 6).

The publication changed the assessments of monopolies and thus the discussion regarding the regulation of them. While it was sufficient before to face high economies of scale to be identified as a natural monopoly, now non-subadditivity, sustainability and contestability were added to the discussion. For example air lines were until the publication assumed to be natural monopolies. The introduction of the argument of sustainability and contestability, in terms of airlines confronted with increasing numbers of passengers and freight, sustainability was no longer existent as demand steadily increases and thus allows new competitors to enter the market, as well as the fact that planes are easy to introduce and readjust on new routes in cases of decreasing demand.

These properties are described in detail, including their relevance within networks in the following sections.

3.3.3.1 Subadditivity in Networks and Services

The most important condition of contestable markets is the concept of subadditivity. The cost function is strictly subadditive, if for all produced outputs at any amount it is cheaper to produce in one firm than producing the good or service by any combination of smaller firms (see Baumol, Panzar, Willig (1982), p. 17, p. 170.). They proved that economies of scale are necessary for the existence of a natural monopoly but not sufficient. This is especially important in the case when one company produces several complementary products. Here, Spence (Spence (1983), p. 985.) shows that "complementarities in production outweigh scale effects". This means that, even if no scale effects are prevalent, complementarity in production can lead to subadditivity.

Subadditivity does not only compare the output and costs in the marketed amount as economies of scale and scope do, but also compares any output and cost up to this point. In this regard it is a global concept, requiring very explicit information about the production function (e.g. Sharkey (1982); Baumol, Panzar and Willig (1982), p. 173).

As physical networks are faced with high sunk cost and a long lifespan, subadditivity of costs seem to be prevalent on a local level. But Kaysen and Turner already pointed out in 1956 that the critical point in the task of determining economies of scale is to define the market correctly (Kaysen, Turner (1956), p. 191). This is even more severe for the concept of subadditivity in the multiproduct case, which will not be discussed in detail, while for each sector and for the services included subadditivity will be discussed separately in chapter three.

3.3.3.2 Sustainability in Networks and Services

Baumol, Panzar and Willig (1982) describe a sustainable market as a market where the supplied quantity equals the demanded quantity at a given price. No producing firm faces losses, and the whole produced quantity is sold. The market is sustainable if no entrant faces any marketing opportunity to enter the market without losses (Baumol, Panzar, Willig (1982), p. 5, p. 9).

Two developments have to be discussed here. Firstly, infrastructure faces increasing demands based on economic developments and changed societal expectations. While some infrastructure networks are already congested, other provided goods and services will face an increasing future demand. This imposes the necessity to establish a duplication of the network to be able to serve the whole demand and thus impose competition. Secondly, technological developments impose competition from new infrastructures, for example mobile versus landline telephony, and thus decrease actual and future demand. Currently, increasing demand for most infrastructure services creates a demand for more, non-congested infrastructure networks. This includes the possibility for new parallel networks, based on the old technology or the development of new competing technologies. Whether sustainability is prevalent in each particular network will be discussed in detail chapter four.

3.3.3.3 Contestability in Networks and Services

Contestability states that a market is accessible to any potential entrant. This includes the following assumptions: The entrant can use the same production technology, the same input prices and serve the same market demand as the incumbent can (see Baumol, Panzar, Willig (1982), p. 5). This is in the sense of Stigler's definition of a free market entry, stating that any company planning to produce and sell the same good or service does not face any cost or production disadvantages compared to the incumbent (see Growitsch, Wein (2004), p. 23). In addition, "the potential entrant evaluates the profitability of entry at the incumbent firms' pre-entry prices" (see Baumol, Panzar, Willig (1982), p. 5). Thus the entrant acts rational by anticipating the hit-and-run-assumption, that if he undercuts the incumbent's price slightly, he will be able to serve the whole market plus the additional demand based on the lower price (see Baumol, Panzar, Willig (1982), p. 5). Growitsch, Wein (2004) summarize the second assumption in the sense that the entry lag of the entrant (the time between deciding to produce and the actual "hitting" of the market) must be smaller than the price adjustment lag of the incumbent (Growitsch, Wein (2004), p. 23) for the market to be contestable.

Contestability seems to be one of the most relevant points in infrastructure. Constructing new physical networks costs money, which leads to sunk costs and takes time. Thus the time span to adjust prices for the incumbent when facing a market entry is comparatively long. This is also true for long-term contracts, covering years, a common example in some mobile telephone markets. Thus contestability might not be prevalent in every market and has to be discussed in detail for each sector separately.

A last point to mention within the topic of monopolies is the so-called X-Inefficiency, developed by Leibenstein in 1956. This effect describes the fact that monopolies do not have the incentive to produce at minimal possible costs, although other economists argue that this contradicts profit maximizing behavior of monopolists (see Viscusi, Harrington Vernon (2005), p. 89).

3.3.4 Internalization of Externalities in Networks

The last assumption focuses on whether agents can influence the price and internalize externalities in their decisions. Researchers and politicians focus on monopolies and oligopolies[7] because monopolists tend to set prices above marginal costs. The monopolist has the freedom to choose the best price to maximize his earnings. Therefore, he chooses a higher price than developed optimally in a competitive equilibrium. This has two effects. Firstly, consumers demand a smaller amount of the offered product or service. This sold amount imposes a utility loss on all consumers who bought the product or service at the high price (the utility loss is the difference between the lower competitive price equal to marginal cost and the high monopolistic price) and for those consumers who would have bought the product at a price equaling marginal costs. Secondly, although the amount sold is smaller at the higher

[7] In the latter part, oligopoly market structures will not be mentioned and described separately. The oligopolistic market equilibrium lies between the extreme monopolistic solution and a solution in a competitive market. For a more detailed survey of oligopoly outcomes see for example Tirole (1988).

price, the monopolist earns more than he would at a price equaling marginal costs and a higher amount sold. But the profit of the monopolist is smaller than the sum of utility losses of the consumers. Thus a monopoly imposes a welfare loss on the whole economy.

Assuming that at least some infrastructure has properties of natural monopolies, there should be sectors with only one firm, setting prices.

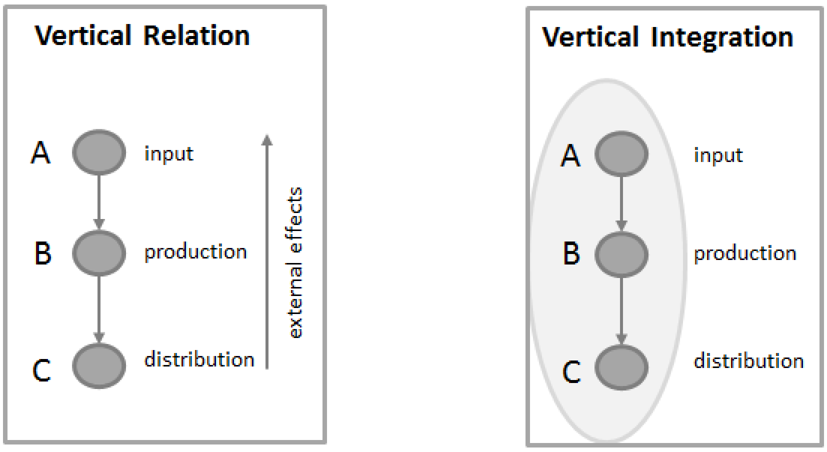
3.3.5 Vertical Integration in Networks

Another important topic in competition and networks are questions regarding vertical relation and vertical integration. Vertical integration and network theory bear the problem that both are often interlinked and not discussed separately.

Since networks are usually based on systems which are ideally vertically integrated, mixing up network theory and theory of vertical integration seems tempting. Considering for example an oil network: there is a root node where the oil is exploited, then the oil is refined, transported in pipelines and distributed to households, companies or petrol stations. This network can be vertically integrated, but does not have to be. A lot of different industries exhibit features leading to opportunities for vertical integration, e.g. the computer industry with the necessity to provide compatible hardware parts and software.

Economides (1996) states "that many important non-network industries have many essential economic features with network industries. These non-network industries are characterized by strong complementary relations." (Economides (1996), p. 673). Thus hardware and compatible software thus to industries with important complementarity being mixed up with network industries, relying on compatible networks.

Bühler ((2004), p. 15) describes vertical relation in networks as "the production and selling of differentiated final products provided over a network is viewed as a vertically related industry".



Source: Modified Extension based on Economides (1996), p. 667

FIGURE 8: Structure of Vertical Integration

Often vertically integrated firms are developed by mergers. According to Viscusi, Harrington and Vernon (2005), a vertically integrated firm is a firm which can be replicated by a "buyer-seller relationship" (Viscusi, Harrington and Vernon (2005), p. 236). It is the basic decision "whether to "make or buy" an input" (Viscusi, Harrington and Vernon (2005), p. 237 or Kranton, Minehart (2000)).

I will discuss various topics relevant to vertical integration based on the following very easy structure: an input supplier A delivers inputs to a manufacturer B, who sells the product to a distributor C, who finally sells the product to the end user.

Vertical integration has several benefits. The summary here follows Viscusi, Harrington and Vernon (2005). A more detailed summary and an in-depth analysis of different outcomes of vertically integrated and non-integrated firms, as well as the structure of analysis, can be found in their chapter on vertical mergers and vertical restraints (Viscusi, Harrington and Vernon (2005), p. 235pp).

Vertical integration may enhance technological procedures in terms of efficiency. It is faster and cheaper to use iron when it is still hot and integrated in the production of steel than using a finished iron product which is then transported to the steel mill and reheated (See Viscusi, Harrington and Vernon(2005), p. 237).

Another source of benefits in vertically integrated companies are transaction costs. Here Viscusi, Harrington and Vernon (2005) differentiate between coordination costs and motivation costs (Viscusi, Harrington and Vernon (2005), p. 237). Transaction costs can be seen in the need for cost reduction to find the required product at the minimal price.

Motivation costs, by contrast, indicate the different incentives between the vertically related firms A; B and C. The producing company B would prefer the distributing company C to deliver good customer services, which usually requires training. If there is a possibility of buying the product at a lower price somewhere else, customers will go to the more expensive shop for advice, where training costs increase product prices; however, the customer acts in a price minimizing way and subsequently buys the product in a cheaper store.

The extensive knowledge of the shop assistants thus does not enhance the profitability of seller C, but of producer B. (See Viscusi, Harrington and Vernon (2005), p. 238). Therefore, C faces costs, and B earns the outcome. This inefficient outcome can be averted by vertical integration or specified contracts.

Other cost components are surveyed by Kranton and Minehart (2000) by comparing companies organized in a network and vertically integrated firms. They sum up the outcome in a make or buy decision (Kranton and Minehart (2000), p. 571). The firm decides to produce the compatible parts in house or to create a network and buy the parts. They develop a model to survey whether efficiency of vertically integrated industries is based on input rationing, demand and cost conditions and incomplete contracts (Kranton and Minehart (2000), p. 572).

The second important topic in vertically integrated industries refers to monopolistic market structure of single parts of vertically related companies. Studies differentiate whether one of the players A, B and C is a monopolist (or oligopolist) and analyze how this influences the market structure for the other players in terms of market power and dependency. As different analyses show, when competition is possible because A,B or C are no natural monopolies, every outcome is feasible (See Viscusi, Harrington and Vernon (2005), p. 238 pp).

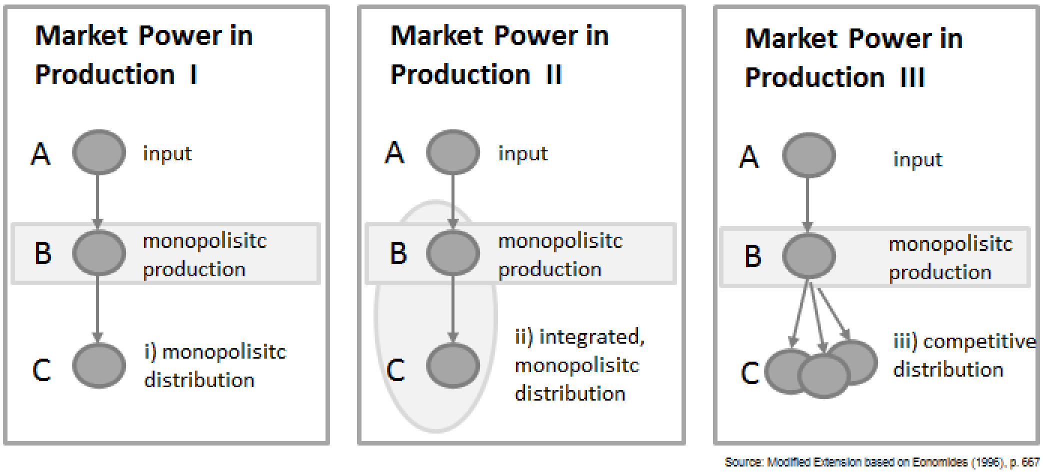


FIGURE 9: Market Power and Vertical Integration

Exclusivity in supply which can be provided by A or B, on the other hand, can increase monopolistic structures. Assuming that a company owns the whole system of landlines and mobile phone receivers, this company consequently can either offer communication services to the end user or can allow exactly one service company or several service providers to use the infrastructure. Allowing several providers leads to competition. Evidently, the infrastructure owner in his position of owning a natural monopoly has the power to create the market according to his preferences.

Tirole ((1988), p. 171pp) differentiates between different topics of vertical integration: intrabrand competition (several retailers in one market, and product differentiation by brands), several inputs (from one or more manufactures), interbrand competion (competition based on close substitutes) and legal status of restraints (patents and fees creating entry barriers). He argues on the basis of vertical externalities set on a model of a monopolistic manufacturer selling an intermediate good to one monopolistic retailer, who sells the final good on the market. The vertical externality is caused by the retailer maximizing his profit based on the price he gets and the costs he has to pay to the monopolist times the amount sold. But if he was maximizing the profit of the manufacturer and himself, he would have to sell a higher amount and thus ask a lower price (Tirole (1988), p. 174). In the integrated industry the profit for the industry will be higher and the consumer price will be lower (Tirole (1988), p. 175). Tirole ((1988), p. 175) summarizes these findings with: What is worse than a monopoly? A chain of monopolies.

This equals the principle of the so-called double marginalization (See Viscusi, Harrington and Vernon (2005), p. 238f). Double marginalization arises when two companies with market power in a chain maximize their profit by high prices and small quantities. Thus the welfare loss for the final consumer is greater than it will be when one monopolistic vertically integrated firm sets monopolistic prices.

Tirole presents a second model where the final good is created out of two goods, the manufactured good of the monopolist and a second, competitively created good, which can also be used as a substitute to the monopolistically manufactured good. He shows that, in this case, the monopolistic good is consumed too little and substituted by the competitively sold substitute (Tirole (1988), p. 179). If the monopolist integrates with the retailer, they both together sell at a lower price, thereby creating a more efficient input mix and selling a higher amount.

So vertical integration is an important topic in network structure and thus for infrastructure. As the short summary of research of vertical integration has shown, monopolistic parts within a vertically related structure decrease social welfare even more than a monopolistic, completely vertically integrated company based on the problem of vertical integration. As the sectoral analysis in chapter four will show, there are in fact several parts of networks which have properties of natural monopolies. Therefore, vertical integration and market power will be an important topic in terms of regulation to avoid excess prices and small quantities of the growth enhancing good "infrastructure services".

Another important point to mention is that vertical integration may support the development of a flexible and efficient infrastructure. But the integration might also increase the integrated firms incentive to keep procedures, adaptations and costs concealed. Especially in cases of PPPs this could become a problem, particularly when price adjustments in public private contracts have to be made (see e.g. Hoppe and Schmitz (2010)). Henckel and McKibbin summarize: "In other words, in a world in which contracts are necessarily incomplete, there exists information rents which the private contractor will attempt to appropriate at the expense of the public contractor. It is possible that the government may gain experience in this repeated game and design better contracts. As of yet, the evidence does not appear to support that possibility" (Henckel, McKibbin (2010), p. 6).

These hypotheses are described in detail for each sector in chapter four. In the next section the relevant discussion of public and private procurement of infrastructure, its historical development and relevant regulatory tools to prevent market power of monopolies are described.

3.4 Public and Private Ownership: Motives for Regulation

The definition of infrastructure, its economic properties and the in-depth analyses of the different sectors (in chapter four) create the cornerstones for the argumentation that at least some parts of infrastructure are natural monopolies. As the history of infrastructure and infrastructure networks have shown, most of them and the corresponding services were, at least at one point of time and in most industrialized countries, provided by the government. Consistently Shleifer, (1998), argues that "half a century ago, economists were quick to favor government ownership of firms as soon as any market inequities or imperfections, such as monopoly power or externalities were suspected" (Shleifer (1998), p. 133). In the late 1980s the picture changed and privatization became the preferred choice of politics, as supported by economic research (see for example Baumol, Panzar Willig, (1988)).

Two different points have to be considered. First, relating to the analyses of infrastructure in detail, some of the infrastructure and especially the services based on infrastructure could be provided in competition, which decreases costs and increases quantity. Second, when goods are publicly provided, this has shortcomings even in cases of a benevolent government, worse if the government is malevolent. In contrast private owners of infrastructure have the incentive to exploit monopolistic structures and thus decrease social welfare. Both types of ownership have advantages and disadvantages which have to be considered and will be highlighted in the next sections.

The first section summarizes agency theory shortly, which describes the incentive structure prevalent between the owner of a firm and its manager. Transferring decision rights from the owner to the manager does not lead the manager to implement the desired actions and outcomes of the owner. The central point of principal-agent theory is that owner and manager have conflicting goals (see Andrews, Dowling (1998), p. 602) and, thus, incomplete contracts and information impose conflicting situations (see Hart, Shleifer, Vishny (1997), p. 1128), which partly can be solved by incentivizing contracts.

Then I will proceed towards the work of Shleifer (1998), and Shleifer, Vishny (1997), who developed the theory of public and private ownership and its shortcomings. Their theory is based on principal-agent theory (Shleifer, (1998), p. 135) and provides the theoretical justification for the privatizations in the 1980s. Until they published their work no model explained why private firms should provide better outcomes than state enterprises (Kikeri, Nellis (2004), p. 92). Empirical analyses found varying outcomes.

The chapter on regulation thus completes the topics agency theory and public/private procurement, based on the argumentation of preventing negative outcomes of monopolistic structures while introducing the upsides of privatization (see also Shleifer, (1998), p. 137). Hoppe and Schmitz (2010) summarize that the topics "importance of cost innovation, its adverse effect on quality, the importance of quality innovation its cost-increasing side effects, and the parties' bargaining power" are relevant when deciding within the framework of private or public provision of a good or service.

3.4.1 Agency Theory and Incomplete Contracts

"The essence of the agency problem is the separation of management and finance, or - in more standard terminology - of ownership and control"[8](Shleifer, Vishny (1997), p. 740).

The analysis so far has concentrated on the structures of markets: monopolistic, oligopolistic or competitive structures and whether the subsector and services have specific properties based on the network formation of the individual subsector. So far I assumed the firm providing the infrastructure or the service as a "black box". Gravelle and Rees ((2004), p. 554) use this expression to describe in their book "Microeconomics" the shortcomings of the standard profit-maximizing microeconomic theory and the input agency theory can give for a closer understanding of how firms act in reality. They summarize the topics to be discussed to understand the decision-making of a firm as: ownership, control, hierarchical structure, information and conflict (Gravelle and Rees (2004), p. 554p) and differentiate in more detail between

1. "the consequences of the separation of ownership from control]...[
2. the firm‘s capital structure]...[
3. the internal structure and organization]...[
4. the 'boundaries' of the firm and the nature of the firm itself]...[
5. the firm's internal labour market" (Gravelle and Rees, (2004), p. 555).

Agency theory concentrates on problems 1) and 3), which arise when different players in a firm with different goals and incentives have to co-operate. Most of the research

[8]As agency theory is not a core topic of this thesis, but an important cornerstone for the development of the hypotheses, I will follow the Article "Survey of Corporate Governance", published in 1997 in the Journal of Finance, written by Shleifer and Vishny. Although this paper was published more than a decade ago, the principles of corporate governance summarized are still up to date. New developments in this field, especially the research of Fehr, concentrating on fairness, are important, but still cannot replace the assumption of the homo economicus as a starting point for economic analysis.

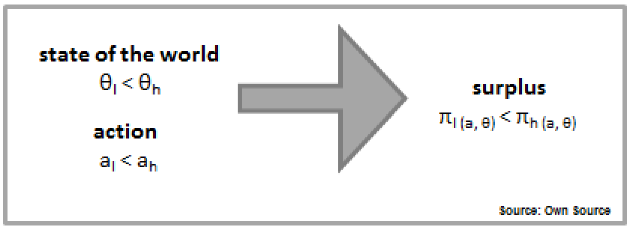


FIGURE 10: Model of Profit Realization

concentrates on the co-operation of the owners of companies and their hired managers. The development of these topics include papers of Jensen and Meckling (1979) as well as Grossman and Hart (1983, 1986) or Hart and Moore (1988). While the first articles listed above concentrate on the theoretical solution of agency problems, many of the following papers focus on empirical findings.

Jensen and Meckling (1976), define the costs arising by these different goals and incentives as "agency costs" (Jensen, Meckling (1976), p. 308) and identify

1. "Monitoring expenditures by the principal,
2. bonding expenditures by the agent
3. residual loss" (Jensen, Meckling, (1976), p. 308).

Summarized this implies that the Principal (P) employs an Agent (A) to manage the company for him. The Agent chooses an action (a) which influences the performance x=x(a,θ). θ is a random variable, indicating the probability of a state of the world (see e.g. Gravelle and Rees (2004), p. 557).

Following the description of Joskow (1997) in "Restructuring, Competition and Regulatory Reform in the U.S Electricity Sector", I develop a simplified setting where the principal owns an electricity network, including the production plant, interconnections, energy control centers and the distribution network. The owner wants his earnings maximized by minimal costs and the maximized earnings as a function of the highest possible price. For simplicity I assume, that he has no competitors and is thus able to exploit monopolistic structures by setting high prices and small amounts. Furthermore, I assume that all electricity is only produced and sold directly to the

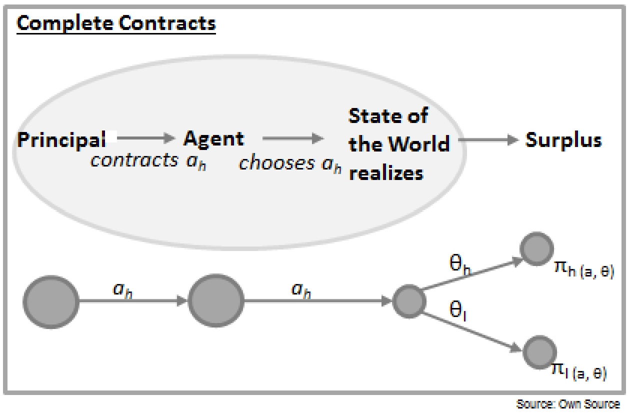


FIGURE 11: Model with Complete Contracts

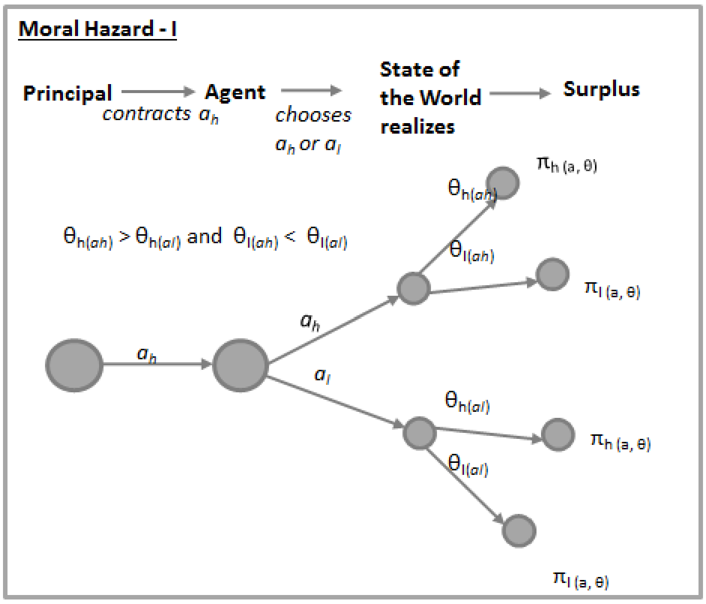
customer and thus exclude spot-market dealing and long-term contracts, which are usually prevalent in electricity markets.

The owner hires an agent to manage the company. He contracts the manager to regularly invest money in network maintenance, thus imposing specific tasks on the manager with extra costs for the owner. The manager does not like to invest in maintenance, because this implies he has to hire a maintenance company, to decide where in the network maintenance and investments are needed and and monitor the necessary work.

But the owner knows that regular maintenance and investments reduce the probability of power outages[9], which on the one hand side are expensive because the damages are more expensive to repair and on the other hand prevents earnings in these times. So he wants the maintenance to be conducted regularly and investments made when needed.

θ can be seen as state of the world which realizes, in our example blackouts and no blackouts. For simplicity I assume that the manager has the choice between investing money and time in maintenance and thus increasing the possibility for a good outcome and no blackout, or being lazy and thus increasing the possibility of a blackout. When the principal is able to determine the action 'a' of the manager he can reward whether he worked hard and achieved a bad result based on a bad

[9]The blackouts in California in 2001 for example were blamed to be caused by under-investments into the infrastructure network (see e.g. Egert (2009), p.2).



Source: Own Source

FIGURE 12: Moral Hazard

state of the world. So the blackout can also be caused by some unfortunate event like a healthy tree falling onto one transmission line.

The agent chooses an action before θ (blackout /no blackout) realizes. But the principal cannot control which action the manager has chosen and he cannot observe the reason for the power outage, he only observes the outcome. The agent now has an incentive to choose the action which is most advantageous to him, be lazy and increase the possibility of a blackout or he has an intrinsic incentive to do a good job.

So the challenge is that the principal is not able to determine the action a of the manager and thus cannot reward whether he worked hard and achieved a bad situation based on a bad state of the world outcome or if he was lazy and achieved a good result based on a good state of the world.

Usually the manager has more information about costs, demand and the market in general than the owner. He knows where he can cut costs easily and whether the firm's outcome is based on his effort or the economic situation at a non-influenceable level. In the example of the electricity infrastructure company, it would be easy for the owner to control whether the agent paid for maintenance, but it would be complicated to monitor whether maintenance was conducted in specifically determined areas. Moreover, this is not the only goal the owner has; often several conflicting goals have to be balanced against each other in detail.

Four types of moral hazard problems within the principal-agent-relationship can be identified. The first is the highlighted problem of insufficient effort towards important but unpopular tasks. Tirole (2006) displays the example of cost-cutting by reducing the number of employees. The second problem refers to extravagant investments which are not in the interest of the owner, for example corporate jets (see both Tirole (2006), p. 16). Entrenchment strategies to secure the manager's own position or to avoid takeovers are the third problem of moral hazard. And the last one are self-dealing problems (see Holmstrom, Tirole (1989), p. 117).

Moral hazard problems are usually addressed with an elaborate combination of incentives. The best known and most closely examined incentives are monetary incentives, such as stock options (see e.g. Tirole (2006), p. 21 or Gravelle and Rees (2004), p.557). Implicit incentives and monitoring are two other important means developed to meet the obstacles of conflicting goals.

To assess whether the state of the world was advantageous or not for a specific industry, competing firms are usually used as a benchmark for the principal to evaluate the action of the manager. When every competing company was successful within a specific period, the manager of an unsuccessful company might not have chosen the desired action. In contrast when the whole industry has faced a troubled year but one company showed outstanding results, the manager might have done everything right or taken hazards, which might be equally harmful to the company. In monopolistic structures this benchmark does not exist (Tirole (2006), p. 28).

In the discussion of infrastructure provision and its parts with monopolistic structures, the lack of competitive potential influences the principal-agent relation within the company. As I will emphasize in the next paragraph, in publicly owned companies the moral hazard problem and its prevention is more complex than in privately owned companies.

3.4.2 Public Ownership, Private Ownership and Agency Theory

Public provision of goods and services was for a long time seen as the best solution in cases of market failure based on external effects or monopoly power (e.g. Stiglitz (2006)). In the 1980s and 90s, public provision was newly associated with inefficiencies and thus privatization was the preferred method of these years. Here I will discuss some downsides and upsides of public and private provision of goods and services. In this discussion of the dissimilarities of public and private ownership of companies and provision of goods and services two topics will be distinguished:

1. Inefficiencies based on patronage or corruption of politicians abusing their power to achieve personal or political goals;

2. Inefficiencies based on incomplete contracts and based on conflicting goals.

Governments and private firms have different goals. While a private firm wants to maximize earnings, supported by a minimization of costs, governments want to provide a specific good or service in a specific quality and often at a specific price. The provision of transport infrastructure for example increases productivity and thus economic growth (see e.g. Dewenter, Malatesta (2001), p. 320). Earnings thus have less priority than they have to private firm owners, so it is expected that private firms are able to provide the good or service at lower costs than the public company is able to. Beside the pure provision of a good, politicians often want to put their engagement towards political advantages with the public company.

3.4.2.1 Social and Political Objectives

Employing excess labor is one of the most often cited arguments against public provision of goods (see e.g. Boycko et al.(1996) or Shleifer, Vishny (1994), p. 995). Excess labor relates to different dimensions. Layoffs send negative signals in democratic countries and thus are often minimized so as not to prevent reelection. It is assumed that more people are hired than needed (Boycko et. al.(1996)), also to convince union leaders to support the governing party.

But a high number of employees is not necessarily bad. Bühler ((2004), p. 13) considers the "ill-fated reform of the British railway system" or the "turmoils in the Californian electric power industry" of 2003 as cases which did not yield the expected results of privatization, the reduction of employees assumed to be the main reason for the failure.

Another topic, summarized as patronage and corruption, is the hiring of connected or politically important people as managers, even if they are not the best qualified for the job (see e.g. Krueger (1974), p. 292 or Shleifer and Vishny (1994), p. 995).

The third phenomenon to mention in terms of public provision of infrastructure is empire building (see e.g. Araujo, (2011), p. 3). As infrastructure has high costs, a high time lag and cannot be easily used in different locations, markets or with other means, infrastructure investments seem to be highly correlated with the politician in power. Airports e.g. often are named after the initiating politician, thus becoming a self-created monument.

The most important political objective concerns the topic of bankruptcy. While a private company usually goes bankrupt and managers and employees get laid off even if the company is sold, this is often not true for public companies. As the produced good or offered service has an economic impact, bankruptcy often is prevented by subsidies. Anticipating this, public employees, who cannot easily be laid off, do not face the same risk as managers in private companies. The result of this so-called soft-budget constraint is that managers of public companies do not face an external incentive to reduce costs, improve procedures and services, invent new products and thus increase the earnings of the company (see e.g. Araujo (2011), p. 3). This leads directly to the second topic of public provision of goods and services: incomplete contracts.

3.4.2.2 Incomplete Contracts in Public Provision of Goods

As the short summary of principal-agent theory has shown, managers and owners have different goals regarding the company and the efforts expected. While in most models it is assumed that the manager is expected to increase the value of the firm, the goal for governmental enterprises might be different. When contracts are complete, the government can contract anyone to produce and offer any good or service with the contracted costs, amount and quality (see e.g. Hart, Shleifer, Vishny (1997), p. 1128).

It is argued that, in cases of incomplete contracts, private companies reduce quality in order to decrease costs. Hart, Shleifer, Vishny ((1997), p. 1128), in this context quote the fear that private schools reject hard-to-teach-pupils or private hospitals expensive-to-treat patients. To test for this relationship, they develop a model where the manager can choose between cost-cutting or inventing which increases the quality. In addition, cost-cutting has an adverse effect on quality, thus decreasing the quality. They find that the more significant the effect of cost-cutting on quality is, the better public provision is to be rated (Hart, Shleifer, Vishny (1997), p. 1130).

So while in most models about public or private provision arguments of non-existent incentives are in the center of the discussion, Hart, Shleifer, Vishny (1997) add "quality" to the discussion of public versus private ownership and provision of goods and services, thereby introducing a new dimension.

3.4.2.3 Privatization and Deregulation

As Newbery ((1997), p. 358) put it: "Privatization is not equal to liberalization or deregulation". While privatization describes the sale of a public company to a private owner or an initial public offering (IPO) of a company to the public, it does not mean that the company has automatically every freedom any other company in the country has. Especially in industries which were assumed to be natural monopolies, privatization was accompanied with regulation of the specific industry.

But "deregulation was touted in the economics community as the single best approach, promising increased production efficiency, lower prices and better services" (Crew, Kleindorfer (2004), p. 3). So privatization is advantageous if the amount and the quality can be contracted properly. Privatization can become a problem when efficiency gains in costs and processes affect quality and amount. Infrastructure investments are long-term investments, needing high investments to produce long-term outcomes.

3.4.3 Theory of Regulation

When talking about privatization and liberalization of industries, it is not only the topic of public versus private ownership but also a question of control and its tools: the direct control of the provision of the good or service by a public ownership or the indirect control by regulatory means (see Newbery (1997), p. 357p). The deadweight loss (Posner (1974), p. 1) adds to the rents of consumers and monopolist. Since infrastructure has positive spillover effects on economic growth, this deadweight loss is not in a country's interest. Therefore, the government always has to decide regarding the following very simplified graph (this follows the graph published by Crew, Kleinfeld, ((2004), p. 5). The deadweight loss and the rents generated towards the monopolistic company is worth regulation and the associated prices and costs created by regulation (e.g. Crew, Kleindorfer (2004), p. 5).

So regulation of infrastructure is not only important to consumers and might influence productivity and national income but also influence private investors in infrastructure. Thus the regulatory environment influences investment decisions by affecting timing and return on the investments (see e.g. Araujo (2011), p. 2). The state has several means to regulate markets:

1. Regulating body - are these politicians or is there a regulatory agency on a federal or national level, staffed with experts?
2. Public ownership of a company in the specific industry, as a competing company, setting levels in price and quality.

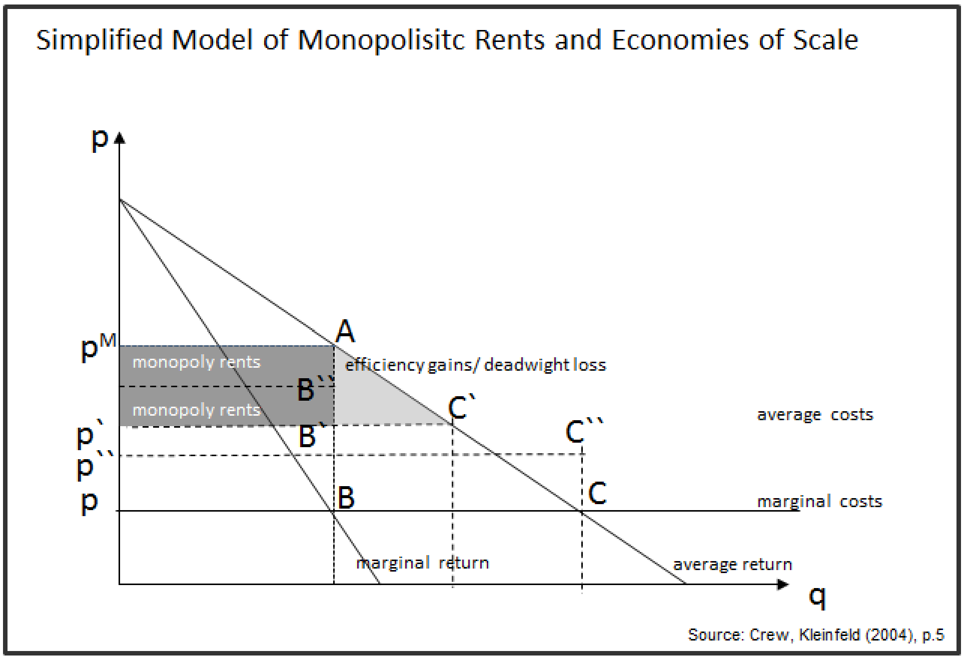


FIGURE 13: Rents in Monopolies

3. Market entry of potential competitors. In some countries and industries, market entry is restricted.

4. Regulation of vertical integration.

5. Price regulation and access price regulation.

6. Quantity regulation.

Each of these regulatory means has a different influence on the market output.

I want to note here that there are two different topics in the discussion of regulation of infrastructure to bear in mind. First, when there are monopolistic structures in an economically relevant industry, regulation could be in the interest of the country, the customers and other companies. The most resolute way to create socially optimal market outcomes is governmental ownership and production accompanied by all negative outcomes described in the last chapter. Second, as I will show in the following paragraphs, not every type of regulation supports competition or competitive outcomes but indeed can increase the persistence of monopolistic structures and prevent competition and harm a country and private customers as well as industrial customers by high prices and low quality when privatized. Just imagine the electricity generating and distributing industry, when there is no incentive to have a reliable fairly priced network, competition of products of electricity-intense production industries on a global level is impeded.

In contrast to this stands Newbery ((1997), p. 358): His "thesis is that introducing competition into previously monopolized and regulated network utilities is the key to achieving the full benefits of privatization. Privatization is necessary but not sufficient. Regulation is inevitably inefficient. Replacing regulation by competition for network services can increase efficiency".

This is equivalently supported by the development of the theory of regulation. It started as public interest theory, hypothesizing that regulation was only implemented in cases of market failures (Viscusi et. al. (2005), p. 357), but was realized to be inconsistent with empirical findings. This theory, which should be interpreted more like a hypothesis, was then followed by another hypothesis, the so-called "capture theory", which expected regulators to be "captured" by the industry. This hypothesis assumes that regulators implemented regulations to support producers rather than maximize social welfare. Today the theory of economic regulation provides models to assess whether regulation is in the interest of the producer or social welfare (see for all and a very in-depth discussion (Viscusi et. al.(2005), p. 357pp).

3.4.3.1 Regulating Body

Every country has different structures regarding their regulating bodies. In some countries, some infrastructure sectors are regulated by federal or national agencies and some sectors are regulated by politicians or political boards.

One expects a regulatory agency to provide more consistent rules than a politician or political board, which might be trying to appeal to voters or please lobbyists. This argument follows Stigler (1971) and the so-called capture theory (Viscusi et. al.(2005)). Additionally an independent regulatory agency is independent of political pressures, and regulatory decisions can thus be expected to be more reliable and transparent for investors in infrastructure networks (Araujo (2011), p. 4). This is especially true when they are based on experts' knowledge.

As the United States, the European Union and countries like Mexico started to introduce cost-benefit analyses regulations (see e.g. Hahn, Tetlock (2008), p. 68), the independence and transparency of the regulating body has become increasingly important.

3.4.3.2 Market Entry

Market entry of competitors and its regulation is an important issue. According to Stigler (1972) "regulation is acquired by the industry and is designed and operated primarily for its benefits" (Stigler (1971), p. 3), and he goes on to point out that "every industry or occupation that has enough political power to utilize the state will seek to control entry" (Stigler (1971), p. 5). This argumentation, following public choice theory supports the hit-and-run argument of Baumol et al. cited in the chapter of monopoly power. Excess earnings and deadweight costs can be gained when entry barriers exist.

While mostly entry barriers in terms of time lags and sunk costs are discussed, here another dimension of entry barriers occurs: legal requirements and procedures to be passed, legal costs of market entry and the duration of the procedures required for market entry take (see e.g. Djankov et al. (2002), p. 1pp). Another regulatory entry barrier can be seen in necessary licenses or certificates (Svorny (2000)).

In public choice theory it is assumed that entry barriers prevent competition and therefore are socially harmful, in contrast public interest theory expects the opposite. The argumentation is that entry barriers allow governments to control for the quality of products, the internalization of external effects and the ensuring of minimal standards (see e.g. Djankov et al (2002), p. 2p). According to Svorny (2000) licenses and certificates reduce information asymmetries, assure quality and additionally resolve the lemon problem by introducing a minimal price and thus attracting only qualitative providers (Svorny (2000), p. 302pp).

Empirical findings tend to support the view of public choice theory that entry barriers reduce competition and thus are in disadvantage for the consumers. Djankov et al. (2002) find in an empirical study that stricter regulation of entry does not lead to higher quality, the internalization of external effects (pollution or health) or increased competition (see e.g. Djankov et al (2002), p. 4pp). This is equally supported by the development in the telecommunication sector. The technological development increased competition between systems (mobile versus landline). Thus in almost all OECD countries market entry was liberalized and exerts now high pressure on incumbents and thus decreased prices (Boylaud, Nicoletti (2000), p. 5pp).

3.4.3.3 Regulation of Vertical Integration

The regulation of vertical integration is of importance as vertically integrated companies might use their cost advantages to distort competition and "restrict capacity strategically in order to deter entry of other downstream service providers" (Araujo (2011), p. 4). Competing firms by contrast would need to reduce costs and increase efficiency (Araujo (2011), p. 4). So predatory pricing against competitors or within networks and service providers in these networks should be prevented.

The chapter on vertical integration has shown, that vertical integration, in cases of chains of monopolies, internalizes the external effects of monopolistic structures and realizes smaller prices and a higher amount of sold products than a not integrated chain would. On the other hand, when competition in parts of upstream or downstream sectors exists, vertical integration could decrease competition and thus lead to socially unfavorable results.

Acemoglu et al. (2005) show in an empirical study that vertical integration is an industry specific phenomenon. It is affected by entry regulations (as discussed in the chapter above) and the development of the capital market. The better the capital market is developed, the less vertically integrated firms are prevalent on the market (Acemoglu et al. (2005), p. 1pp).

Nevertheless the OECD in its ETRC indicator for regulation assesses for typical vertically integrated sectors the degree of vertical integration and differentiate between integrated or separate companies and companies with separated accounting strategies. They specifically ask whether the whole sector is bundled, unbundled or mixed (see Conway, Nicoletti (2006)).

3.4.3.4 Price Regulation and Access Price Regulation

To avoid access pricing, price regulation of the good or services or network access seems straightforward when it comes to regulatory tools.

The easiest and most frequently used type is the so-called rate-of-return regulation, where the regulated company is allowed to earn a specific amount or rate of return for their capital ($\sum_{i=1}^{n} p_i q_i = costs + fairrate * base$) (see Viscusi et. al. (2005), p. 434). A so called "fair" rate "should allow the firm to recover investment costs" (Egert, (2009), p.5).

This mechanism has two shortcomings. First, the regulator needs information regarding costs so as not to over- or underestimate them. Second, the fair rate and the base rate have to be determined in regular hearings, which leads to regulatory lags. This regulatory lag has an upside - the regulated company has an incentive to reduce costs and increase efficiency while the actual fair rate is in charge. All gains achieved during the lag time belong to the company.

The downside is the so-called Averch-Johnson-Effect, which incentivizes the company to use more capital than labor when the fair rate is higher than the rate of return of the capital market. But even the Averch-Johnson-Effect has an upside, as the high capital intensity often leads to faster technological change (see Viscusi et. al. (2005), p. 435 or Egert (2009), p. 5). In contrast, according to Starkie (2006), the high capacity intensity introduced by the rate of return regulation might also be used to deter entry or to incentivize managers for empire building, two severe downsides.

To offer a stronger incentive for cost reduction and efficiency gains, different types of price regulation were developed, so-called incentive regulations.

The first to mention is the earnings sharing, indicating that gains from cost reduction and efficiency can be kept at least in parts, depending on the gained amount.

The second frequently implemented mechanism is a price cap, which leaves all cost reductions to the company. It includes an inflation factor, the anticipated production gains the company will make within the next period and a factor to control for costs which cannot be influenced by the company. Studies show that price caps lead to low prices. But the more often price caps are adjusted to lower costs, the more the mechanism resembles a normal rate-of-return regulation; cost-cutting gains are no longer attributed to the company (see Viscusi et. al. (2005)).

As price caps are not concerned with quality features of the product or service but incentivize cost reduction, they can lead to lower quality in cases where cost cuts are strongly correlated with quality decreases (see e.g. Egert (2009), p. 6).

A theoretically well discussed principle is yardstick regulation, which equals a regulation based on a benchmark of a company from another region. The problem is that it is hard to find comparable companies in terms of cost structure, market demand and investment history (Viscusi et. al. (2005) p. 442), so that yardstick regulation so far has not been applied to a broad area of industries, only in the electricity industry (Cossent et al. (2009), p. 1147).

3.4.3.5 Quantity Regulation

Quantity regulations usually take two forms. The first form usually indicates that a company has to provide its service within a specific area to all customers in a specific quality. The second type also includes a specific price for which a region has to be served.

This regulation imposes high costs on infrastructure companies when they need to accommodate a sparsely populated area. Infrastructure networks, as explained in the theoretical part, show indirect effects of networks by scale effects; this regulation imposes problems on the earnings of the company, or even worse, when the price, as in the second type, is given and is lower than the average costs, the fixed costs are not covered.

3.4.3.6 Other Types of Regulation

When discussing regulation, there are also other types of regulation prevalent, which influence investors and owners of infrastructure networks and providers of services. Important to name are for example noise and air pollution regulations in transport systems, which also influences the refinery industry to develop new products such as unleaded gas (see e.g. Hahn, Tetlock (2008), p. 71). One can also quote quality regulations in freshwater procurement or in the provision of highways to prevent accidents caused by too narrow safety lanes. Although these topics are of high importance in infrastructure industries because of their impact on costs and investments, I will not discuss them here as they cover a wide and differing range for each individual sector.

3.5 Summary of Characteristics of Infrastructure Based on the Definition

According to Economides the important relationship in network industries is that market entry of competitors reduce prices and profits, as it is also predicted in standard microeconomic literature. But additionally, he highlights, in networks, the demand increases the value of the network and thus increases demand further. Following Economides, this is the explanation why companies offer their standard to be used by competing companies (Economides (1996), p. 213).

Summarized, the following characteristics are important for firms active in network industries:

- Direct and indirect network effects:
  Directed and undirected networks profit from an increasing network size. The

more consumers participate, the more advantageous it is to be in the network; the demand for network services increases, consequently increasing earnings. This is true for directed networks with indirect network effects, but the impact is even greater for undirected networks with their additional direct network effects.

- Ownership and operation of nodes or edges:
  A firm active in root-nodes or end-nodes will face competition. Root-nodes and end-notes are competitive, so that performance of the owner of nodes should be inferior to owners of edges.

- Vertical integration:
  When a company is active in nodes, edges and services at the same time, internal price structures should improve the performance of the companies.

- Monopolistic structures: The number of competing companies influences prices and quantity sold. Thus, when several companies are operating within one market and providing the specific service, the price in the market should fall and the amount increase. The discussion in the following sections on public and private ownership supports this assumption, as it is argued that monopolistic companies do not have incentives to decrease costs efficiently. Thus, the more competition is within the market, the inferior is the performance.

The four hypotheses derived from the theory of competition will be empirically tested in chapter five, combined with the different indicators of performance.

With regard to infrastructure, its properties of networks and monopolistic structures, privatization and liberalization have different aspects, which are summarized here. As monopolistic structures are prevalent, a private owner will always have the incentive to ask high prices and sell a socially sub-optimal quantity (e.g. Kikeri, Nellis (2004), p. 97). Furthermore, due to non-existing competition, the manager will not have an incentive to decrease costs or improve efficiency, as there is no benchmark he can be compared to. But the owner would have the opportunity to incentivize the manager by promising him some of the cost reduction and productivity gains.

In public companies, by contrast, cost reductions and efficiency gains, when not contractible, will not be implemented by the manager either. But compared to the private firm, it is hardly possible to incentivize the manager by promising him some of the gains, property of the public company and thus of the public as the public company wants the product or service offered at maximal amount and minimal price in regard of positive effects of infrastructure services on economic growth. Both private and public managers are influenced by empire building, but this incentive might be decreased for the manager of the private company by the costs which decrease his earnings based on an incentivized contract.

Quality is of major concern, an especially evident example is the quality in water and wastewater treatment, as this is essential for human survival. Quality is also important in transportation networks as it speeds up transporting times and improves security, while a low quality might lead to accidents and deaths (insufficient air traffic control results in plane crashes, low quality railway tracks increase the risk of trains derailing)or a non-compatible electricity or oil or gas standard might destroy end devices or lead to explosions.

Thus, following the argumentation of Hart, Shleifer, Vishny (1987), infrastructure goods and services contain a serious quality dimension, which might be influenced directly by cost-cutting measures and efficiency attempts. Reassessing the findings of the first chapter and the properties of infrastructure, I quote Vogelsang (2010), who describes that investments in network industries are based on the fact that economies of scale, the size of investment and the sunkness of costs influence investment risk and the complexity of the investment decision. Combining that with the findings above, physical infrastructure and the quality of infrastructure is of importance and determined by the built structure itself, so that quality might have to be regulated or contracted, following Hart, Shleifer, Vishny (1997).

Vogelsang (2010) also sees capacity shortages or excess capacities as well as wasteful duplicated investments as core problems in the investment decision and especially with regard to the fact that, for example, 5 km of a motorway are useless unless they are an integrated part of a network.

Another argument of the theory of networks is to be reassessed here, the standardization of networks. As the competing rail companies in the US, starting in 1880, showed, diverging network standards impede efficient network structures and impede regional development based on preferred treatment of local advantages. In this case, the need to stop at a station and reload transported goods to another system increased trade and consumption in the area of the reloading area. This malpractice can be assumed to be more prevalent when the infrastructure is owned and operated by the government, as the gains are on the local level and less on the firms' level.

Furthermore, the topic of vertical integration is of importance: two integrated monopolistic companies are better than a chain of monopolistic companies, but one monopolist is able to determine the market structure of the down integrated company by excluding other competing companies.

Thus privatization and liberalization can lead to efficiency gains, reduced costs, lower prices and improved quantity and quality (see e.g Crew, Kleinfelder (2004), p. 3), but, especially when monopolistic structures are prevalent and competition is not feasible, might also lead to socially not sustainable outcomes. To be able to achieve efficiency gains and reduced costs by sustaining goods quality and quantity, governments introduce regulation in markets with monopolistic structure.

Regulation is introduced to challenge these problems in private procurement, which are especially prevalent in infrastructure industries. The short summary showed that regulation is not perfect in reducing the misfits. The regulating body might be corrupted and act favoring goals of politicians or the industry. This is also true for the regulation of market entry. Introduced to ensure quality, the internalization of external effects and a reduction of the deadweight loss, barriers to market entry turned out, according to empirical studies, to be preserving monopolistic or oligopolistic structures.

Price regulation and access price regulation in monopolies at first sight support the reduction of excess earnings. But also here, several structural challenges occur. Distortions towards too capital intensive investments emerged, on the upside creating new technology, on the downside imposing entry barriers. Further, price combined with quantity regulations might prevent companies from being able to cover sunk costs to provide the required quantities in remote areas.

In the analyses of sectors in the next sector some common types of regulation per sector will be introduced, although, as this thesis covers the OECD countries and the infrastructure sectors with several subsectors, the analyses can only give a short and incomplete insight.

Chapter 4

Infrastructure Sectors

In this chapter the taxonomy developed in the last chapter will be applied to the infrastructure sectors identified. This is the foundation for the empirical analyses because the hypotheses assume that different types and parts of networks show different characteristics. The taxonomy is applied on the set of firms in chapter 5.

Today's industrialized economies would not have developed without proper infrastructure. So the sectors included in this chapter are energy, electricity, transport and data transfer (telecommunication). They constitute essential structures for modern business. Energy and electricity resources are needed in production, transport and data transfer. Conversely, transport on roads or water enables the distribution of oil and gas. Data transfer facilitates internationally dispersed production with central organization and reduces the need to travel.

Studies find correlations of infrastructure and productivity growth in manufacturing as highlighted in chapter 2 (see e.g. Holtz-Eakin, Lovely (1996); Morrison, Schwartz (1996)). Thus, a smaller amount of infrastructure and services offered might have a multiplied negative effect on the economy. Services or goods offered at higher monopolistic prices and smaller amounts lead to the in chapter 3 described welfare loss. The normal monopolistic welfare loss is additionally intensified in infrastructure sectors by their positive external effects to other industries and consequently on economic growth. This is the reason why governments try to avoid monopolies in industries with positive external effects, such as infrastructure. In the following part, the sectors and sub-sectors are described in detail, assessing the network structure and whether monopolistic characteristics are prevalent.

For each sector a short section on regulation will be added, although the topic of regulation for different sectors, covering the development of privatization, liberalization from the beginning in the 1980s until today for all OECD countries can only be a short insight instead of an extensive in-depth analyses.

4.1 Telecommunication

When discussing networks of telecommunication one usually imagines the typical landline telephone communication network as most publications do. But typically telecommunication refers to the transmission of information between distant places (see e.g. Faulhaber, Hogendorn (2000), p. 306) so it includes all types of transmission of data over significant distances. All systems face a significant technological development which started in the late 80s (see e.g. Laffont, Tirole (2000), p. 9).

Today data can be transferred on physical structures like wire or wireless. Increasingly digital types of transmission are used, compared to older analogue standards. The data transferred can be for television, radio, telephone, telefax, telegram, as well as any type of electronic communication. While radio and television data are directed in-tree graphs with one sender and several receivers, telefax, telephone and telegram as well as the internet are undirected networks.

The telecommunication sector showed the most visible development within the last years (see e.g. Laffont, Tirole (2000), p. 9). While roads are still made of asphalt and railways usually use rail tracks, compared for example to developed but too expensive magnetic systems (although the speed was enhanced dramatically), the use of mobile phones, internet and mobile internet has become essential within the last two decades. This rapid development not only introduced new technologies and new possibilities, but also created new competitors to the established fixed line telephone markets. Thus most of the literature on monopolistic or network structures focuses on fixed telephone loops and less on mobile developments. In this context the following quote from 2000 discussing the development of demand for internet data transmission highlights the dramatic change within the last decade: “whether or not the forecasted demand for the interactive delivery of graphic and video data actually materializes is hotly debated” (see Faulhaber, Hogendorn (2000), p. 306).

In 2008, Leiponen stated that many telecommunication and computer companies have identified wireless communication as the future of the market (Leiponen (2008), p. 1904). Thus the assessment of Vodafone in 2011 of possible comparative advantages of mobile data transfer versus the contemporary hot topic fiber networks (Vodafone (2011)) follows this development.

4.1.1 Network Structure

Authors differentiate between local loops, connection networks, services and terminals (see e.g. Gabelmann, Gross (2000)). This taxonomy concentrates on fixed line networks, the local loop as the local network, connected with other networks by the so-called connection network, including switches (see Ai, Sappington, (2002), p. 145), working as hubs between the networks. This is the physical structure of the network. Individuals can use the service of the network, the data transmission, by its terminals. Terminals translate the data, so that the user on the telephone can hear the voice, read the fax or access an internet homepage. This is not different from mobile networks. The local loop and the connection networks are based on radio towers (or even satellites) and frequencies which the providers are allowed to use. These networks are undirected.

Radio and television networks are based on the same structures, using fixed lines or frequencies, but are in-directed, from the station to the consumers.

Network Effects

Telecommunication networks typically demonstrate strong positive network effects. It is straightforward that these undirected communication networks are only useful for one user if there is at least one additional user in the network who can receive the data. The more people use a specific standard, the more beneficial it is to the single user. As Cambini and Valetti put it: "communication services cannot be consumed in isolation but involve interdependence between callers" (Cambini, Valetti (2008), p. 708). Thus not only the party making calls but also the party receiving calls benefits from the system (see Cambini, Valetti (2008)). The more dense and varied a network is, the greater is the value for the individual consumer (see Allan (1988)).

Complementarity and Standards

It is obvious that complementarity in undirected telecommunication networks is essential for positive network effects to emerge. Thus standards, as the technological characteristic to achieve complementarity, are especially advantageous to agree on.

Vogelsang puts it that "they are necessary for carriers to provide ubiquitous service and enable end-users to call anybody and be called by anybody without having to sign up with a system wide network monopolist" (Vogelsang (2003), p. 830).

Complementarity in directed telecommunication networks supports the consumption of radio and television shows, so that consumers do not need several receivers for different programs. This is especially true because marginal costs for one additional consumer enjoying the program equals zero once the network is installed. Parallel networks with different standards thus might hardly find a market.

Switching Costs and Lock-In

Switching costs and lock-in are important topics in telecommunication. As computers, television and other electronic devices are durable goods and contracts for telecommunication services often cover a certain time span, changing the provider or the system is faced with high costs, although a tendency towards short-term or prepaid contracts emerges (also for cable television), which increases competition in the markets.

4.1.2 Assessment of Competitiveness

Vogelsang, 2003, (Vogelsang (2003), p. 831) describes the development of the US telephone market when the Bell patents of the telecommunication firm AT& T expired and competing networks emerged which were not interconnected. Customers had to subscribe to several networks to be able to be reached by anybody, which resulted in problems especially in business environments. When AT& T gained new patents for more viable long-distance calls and refused to interconnect with their competitors, competitors could not offer the same service. AT& T gained high market shares and created a monopolistic structure. It was not until later that access regulation enabled competition in the market.

Thus in fixed line telecommunication might exist a tendency to develop monopolistic structures if one incumbent has advantages based on technology or the density of his physical network.

Subadditivity

Subadditivity describes a situation when it is cheaper for one company to produce all output instead of different competing, smaller companies. All industries with high fixed costs and high capacities seem to be not subadditive. Telecommunication faces high sunk and fixed costs especially in fixed lines. Duplication of fixed telephone lines and cables, satellites and radio towers is only reasonable if capacity is congested and demand still rising (e.g. Growitsch, Wein (2004), p. 27; Grajek, Röller (2009), p. 4).

Contestability

Contestability in the sense of Stiglers free market entry is limited by patents and technological advantages. Furthermore, if the entrants' network is not interconnected with the incumbents' networks, the consumer effects of the networks are small and thus the entrant will not face the same demand as the incumbent does.

In the interpretation of Growitsch and Wein (Growitsch, Wein (2004), p. 25pp) regarding the hit-and-run assumption for monopolistic structures the entry lag and price adjustment lag determine contestability. Constructing any telecommunication network requires considerable investment and time, for implementing both, radio towers or fixed lines. The price adjustment lag of the incumbent is proportionally short, he only has to adjust the invoice algorithm (see Growitsch, Wein (2004), p. 27).

Sustainability
Sustainability describes if there are market demands not met by actual supply. Growitsch, Wein are in 2004 convinced that there is still capacity in telecommunication (Growitsch, Wein (2004), p. 27). In contrast to that is the current discussion of how to treat data packages on the internet, based on emerging problems of congestion.

4.1.3 Regulation

Telecommunication for long has been either state regulated monopolies or state owned and operated companies (see Sarkar, Cavusgil, Aulakh (1999), p. 363). This was based on security concerns and the assumption that telecommunication is a natural monopoly (see Sarkar, Cavusgil, Aulakh (1999), p. 363).

But within the last years liberalization and privatization of the telecommunication markets have evolved. The so-called local loop unbundling describes the development that the incumbent operator provides access to his chopper line for a reasonable price. Reasonable denotes the price needed to recover incumbent's costs and allow fair and sustainable competition on the service level (see Bourreau, Dogan, (2005), p. 175). But it is still discussed whether competition should include facilities or only cover services (see Bourreau, Dogan, (2005), p. 174).

Regulation is prevalent in almost all OECD countries (according to CESifo dice (http://www.cesifo-group.de/de/ifoHome/facts/DICE/Infrastructure /Communication-Networks/Regulation.html)) in the form of issued licenses, the control of license requirements, approval of merger regulation and regulation of service quality. Furthermore within the EU different laws were introduced for communication within the EU countries (Veith (2007)). An example to avoid excess earnings are the mobile roaming prices, which should be overcome by EU regulation (see Cawely (2012), p. 48 and http://ec.europa.eu/deutschland/press/pr_releases/11660_de.htm).

4.1.4 Summary of Findings in Telecommunications

The single network systems still show monopolistic structures from themselves, resulting from high sunk costs. Nevertheless the different systems are competing with each other: broadband fixed lines are contested by cable TV providers (see Grajek, Röller (2009), p. 2), are both rivals of mobile telecommunication (see Hellwig (2008); Vodafone (2011)). Calabrese highlights in 2007 that even municipal Wi-Fi systems start to compete with telephone companies (see e.g. Calabrese (2007), p. 123).

Already in 2000 Faulhaber and Hogendorn realized that broadband internet services could develop from telephone, satellite or cable networks (Faulhaber, Hogendorn (2000), p. 307).

An open point to discuss is whether oligopolistic structures develop, which may be particularly relevant to telecommunication, with a small number of players facing a limited number of international market opportunities (see Sakar, Cavusgil, Aulakh (1999), p. 365); however, this has to be seen in the broader context of competing systems.

Another issue to be aware of is congestion. In 2001, Röller and Wavermann (see Röller, Wavermann (2001), p. 911) wrote that "for instance, in transportation infrastructure no such positive network externalities exist. In fact, there might be significant negative network externalities present in transportation, resulting from congestion" and they put that in contrast to telecommunication: "the more users, the more value is derived by those users" (see Röller, Wavermann (2001), p. 911). This becomes untrue when the internet provides more of radio and television related data than today. The increasing demand for telecommunication services of the past years started a discussion about how to handle high data requests. Today the requests are served on a first come first serve basis, but if this is the right solution or, as in cases of congested roads, a toll should be implemented is a matter of debate (see Viscusi, Harrington, Vernon (2005)).

It is straightforward that services and terminals (telephones, faxes, mobiles, TVs etc.) are not monopolistic, as they are already competing (see Growitsch, Wein (2004), p. 28). The bulk of mobiles, telephones, televisions and computers can be bought and mostly adapted easily to the different standards. Different telephone operators can be chosen, connecting everyone with anyone.

4.2 Transportation

The first transportation networks evolved far back in human civilization as road networks (see e.g. Vickerman (2004), p. 177, who refers to bridges that have been privately owned and financed for centuries. Grigg (2010), p. 19, underlines this by even going back to ancient times.). This accounts for today's especially large and developed road networks. By definition, transportation networks geographically connect different economies and facilitate trade. The higher the quality of a network (with regard to size, technology and connections), the faster any destination can be reached and goods and services can be exchanged. This illustrates the positive spillover effects transportation infrastructure has for the economy. The different sub-sectors show individual characteristics and impact on the economy.

Within the economic infrastructure sectors, transportation is receiving the largest amounts of investments (see Grigg, (2010), p. 65). The sector of transportation includes aviation, road, rail and waterway transport[1]. All these sectors can be classified according to what they transport (passengers vs. freight goods) and the distance of transport (local vs. long-distance) (see Viscusi et al. (2005), p. 590).

[1] Although it can be argued that the oil and gas, telecommunications and electricity sectors offer transportation-related services, I do not consider them as transportation sectors, since they service special freight goods (see also Viscusi et al. (2005), p. 589).

The topic of regulation in transport mostly tries to internalize positive and negative externalities like e.g road damage costs, congestion costs, safety hazard, green-house-gas (GHG) emission, local air, noise and light pollution (see e.g. Hepburn (2006), p. 239), most of them focus on the individual using transport services. Other regulations, like e.g. safety hazards, quality, quantity and price are specified in contracts of public private partnerships. These are the most common forms of privately building and operating transportation infrastructure. Sector specific types of regulations are given in the description of each subsector.

4.2.1 Road Network

Road networks are the oldest and most important transport networks, starting with a simple trail, improving to a cobble-stoned road up to an asphalted street. Any of these grown or planned and built structures are a basis for traveling and transportation. Means for this service are walking on one's own feet, a horse, pulling a cart, driving a bike, a motorbike or a car, depending on the century, the level of development of the country, the quality of the road etc. Road networks usually consist of edges to be identified as trails or roads or highways. The nodes are the customers' houses, parking areas near supermarkets or malls and the normal crossings, increasing the variance for individual traveling. The services supplied on roads are transporting and traveling services offered by cars, private or public buses and trucks (for an extensive discussion of road-transport systems see e.g. Armbrecht et al. (2008), p. 230pp).

4.2.1.1 Network Structure

The road network is an undirected network with parking lots as nodes as well as crossings and roads as edges. Lighting on crossings and lights are an additional part of many road networks and increase the quality in terms of safety of the network (for a discussion of road networks and regulation see e.g Verhoef, Nijkamp, Rietveld (1995), p. 147p). Verhoef, Nijkamp and Rietveld name three main types of roads:

motorways, imposing the highest standards and designed only for motor traffic; A-level roads such as highways, main and national roads, all outside urban areas; and secondary or regional roads. Various small and paved roads within urban or rural areas are also outlined (see IRF World Road Statistics (2009), p. 8).

Network Effects

Due to high capacities and fixed costs for road networks, every additional user decreases the price for the network and increases the expansion of the network. Only when enough people own a car and want to travel between A and B will the road between A and B will be built in a certain quality. Because only a few travelers are interested in having an expensive road built, remotely situated farms are often only accessible by small dirt tracks. This is highlighted in an analysis of Armbrecht et al. ((2008), p. 230pp) focusing on road transport networks, the networks' quality in terms of congestion and density correlated to population density.

Therefore, the more people in remote areas are participating in a road network, the more destinations can be accessed, depending on the transport vehicle chosen. But there are also huge negative network externalities in terms of congestion due to capacity problems of road networks especially in densely populated areas (see e.g. Armbrecht et al. (2008), p. 230pp).

Complementarity and Standards

In road networks complementarities and standards are not as important as in other networks. Cars and trucks have to have specified dimensions in sizes and weight. Nevertheless the weight of trucks or tanks has to be adjusted to the construction of bridges or sharp turns. Trucks use standards for transporting goods, the type differs between countries, manifested in standardized container sizes (for example freight containers set by the International Organization for Standardization (ISO), ISO 668) and the EUR-palett (EN 13698-1)

Additionally security standards for vehicles and drivers are implemented to prevent accidents. The introduction of so-called focal point is important when individualistic consumption takes place in these shared roads.

Switching Costs and Lock-In

There are almost no switching costs beyond security standards for vehicles and drivers and the size of the vehicles.

Switching occurs between different transport systems like rail and road. In road transport itself no switching costs are prevalent.

4.2.1.2 Assessment of Competitiveness

Road networks are expensive and mostly not competing. Nevertheless routes of different qualities might connect the same two destinations. For example an extensive highway with several lanes exists, offering exits every five km. In contrasts two lane overland roads connect the small towns in the periphery of the highway. While the first is built to travel fast long distances, the second serves short distances of less frequented areas. Traveling the long distance on the overland roads would take much longer. But there are almost never competing highways of similar quality and price between two destinations. This is also based on the straightforward argument that the first highway chooses the direct connection, whereas the competing highway has to choose a longer and thus slower route. There might be cases of congestion where a competing highway could be sufficient. In some countries (e.g. Austria, France), expensive multi-lane toll roads compete with cheaper and smaller roads of lower quality.

Subadditivity

Thus there is severe subadditivity of specific routes. This is based on the fact that duplication is only reasonable in cases of capacity constraints. And here, as argued above, the quality of the duplication might be so low that the second connection would not be used extensively or only in rare cases.

Parking is not subadditive. Trucks, cars, buses and all vehicles using roads are competing and thus not subadditive. The system of traffic lights is subadditive, a second traffic light system on a crossing is absurd and would lead to severe accidents.

Contestability

Roads are not contestable. Building roads and bridges takes time and is expensive. Roads, once built, cannot be transported to other areas where a road is needed more (see e.g. von Hirschhausen, Becker, Tegner (2004), p. 91).

Parking lots can be contestable if they do not have to be integrated into a tight urban area where free areas are available. Building a car park takes time and is expensive (see e.g. Verhoef (1994), p. 276).

The system of traffic lights is not contestable. Implementing a second system on a crossing or even in a city is absurd. One traffic light system additionally enables a city to orchestrate the traffic during rush hour or implement green light phases for public transport systems.

Sustainability

There are many road transport systems which are not sustainable. For example, urban areas usually have capacity problems at least twice per day in rush hours. But while here the duplication can enhance the quality for all network users, no additional area is left.

There are many other roads, especially highways which have capacity left at least most of the time. If a specific part of a highway is crowded only twice per year, a second highway, would not earn enough when financed by tolls, and thus is not required.

4.2.1.3 Regulation

Regulation in road transport is two-fold. Security issues set standards for vehicles but also for the design of roads (see e.g. Hepburn (2006), p. 239). Research papers often concentrate on the question whether toll roads – the pricing of the usage of the road – internalize the external effect of congestion on roads or congested areas like London (see e.g. Hepburn (2006), p. 240, Kerwer, Teutsch (2000) or Verhoef et al. (1996)).

The main instrument in regulating roads are road concessions. The concession prices, compared to licenses in telecommunication, are all determent by the auction structure. Auctioning concessions is the common way to distribute concessions and the expectations of traffic-volume (see eg. Nombela, de Rus (2003)). Regulations are set in the contracts. In a study on toll roads and concessions in the USA and Bel and Foote ((2009), p. 402) it was found that "privatizations were set up as leases in which the concessionaire has the obligation to operate the road pursuant to an agreement with the public owner in return for the right to collect tolls. Title to the road did not change hands."

4.2.2 Air Network

Air networks are special networks, based on the fact that edges are not physically existent (this is likewise true for the edges of water transport networks). But air traffic needs air traffic control to prevent accidents in the sky. The controls function comparably to physical edges of the network. As in the other transport networks the services provided are transport services for goods and people. The vehicles, in this case airplanes, are not part of the physical network. Most of the goods transported via plane are lightweight but valuable small goods. Therefore, the importance of air transport is often underrated in the discussion, compared to shipping transport, which focuses on heavy goods (see e.g. Hummels (2007), p. 134).

4.2.2.1 Network Structure

The air network is an undirected network with airports as nodes and the traffic control as edges. The airports also function as hubs, increasing the number of possible connections (see e.g. Bowen, (2002), p. 427p).

Network Effects

High capacities and fixed costs result in high indirect positive network effects. These network effects are also prevalent for planes. Consequently only some people own their own personal plane.

But these high indirect network effects are especially prevalent for airports and their runways and the air traffic control. The more people fly, the cheaper the individual journey gets. The cheaper a flight is, the more goods are transported by plane instead by cheaper but slower transport vehicles such as trains, trucks or ships.

There are also direct network effects depending on the number of airports. The more airports exist, the more different routes are available and the more people are interested in traveling by plane. In addition, an increase in airports also increases the possibilities of hubs to achieve a most efficient capacity load per route.

Complementarity and Standards

Complementarities and standards are important in air transport industries. Runways have to be long enough, and gangways have to fit the specific type of plane. The more parts are standardized and complementary, the more efficiently procedures during take-off and landing can be executed (see e.g. Bowen, (2002), p. 428; a detailed summary of European airports and quality assessment can be found in Armbrecht et al. (2008), p. 232p) and thus prices are decreasing.

Air traffic control has to be standardized and complimentary, identical to lighting systems in road transport.

Switching Costs and Lock-In

Planes can easily be used on different routes. Switching costs are therefore small between routes. But there are fees and competition regarding starting and landing slots of highly frequented airports, which might impose costs when old contracts are changed to new contracts on new airports.

Of course, the new airports and runways have to meet the needs of specific plane sizes.

4.2.2.2 Assessment of Competitiveness

The airline industry faced rapid changes in Europe as well as the United States. This started with the deregulation in the 1970s, "which ultimately led to the complete absence of price and entry controls" (see Shy (2001), p. 215pp).

Subadditivity

Airports are subadditive. Only some airports are required within a specific region. There are different types of airports: military airports, airports for small planes and big airports, all serving different target groups with different expectations. More airports in one region would decrease fees and taxes of the single airport and thus leading to inefficiencies due to high economies of scale. Duplication can be reasonable if capacity is stressed and increasing the value of the network. But most of the time a single, bigger airport is more effective. Nevertheless, all airports are supported by one single control system within the area.

This is quite different to the service providers. Air planes are inexpensive and their costs quickly recoverable. If one passage turns out to be inefficient, the plane can be used on another route. Both entry lag and price adjustment lags are small. This is in line with empirical findings which show that service providers, such as motor carrier operations or the airline industry, exhibit constant returns to scale (see Winston (1985), p. 65).

Contestability

Airports are not contestable. The construction takes time and is expensive. Once built, the airport cannot easily be used for other means.

Air traffic control is not contestable.

Sustainability

Duplication of networks could be reasonable in cases of constrained capacity. The benefit of an airport depends on the its proximity to the traveler, even though its focus shifts towards profits from commercial activities. Nevertheless the economic viability is still measured on traveling fees (see for airports Freathy, O'Connell (1999), p. 588).

Especially in the aviation industry airports and air traffic control turned out to be a bottleneck within the last years, and demand is expected to be increasing even more in the next years (Klingenberg, Klingelhöfer (2004), p. 105).

4.2.2.3 Regulation

While the airport services in terms of airlines was the first industry to be liberalized and deregulated, based on the research of Baumol, Willig and Panzar (1982), airports are mostly publicly financed. In most countries politicians decide where airports are to be build. Mostly arguments of regional development and the longterm requirements of the capacity determine these decisions (see e.g. De Neufville (1995), p. 174). Nevertheless airports itself show increasing competition between each other, where regulation on charges and anti-competitive behavior exists (Charlton (2009), p. 120).

This is best highlighted by the Australian main airports of Melbourne, Brisbane and Perth. They all were privatized in 1997, followed by several smaller airports 1998 and finally Sydney Airport in 2002. Regulation ranged from a strict RPI-X price caps and developed towards a to the current regime characterized by monitoring and commercial relationships (see Schuster (2009), p. 121pp). The competition between the airports lead to different, but justified (and not excessive) rates. Nevertheless the author of the study underlines, that monitoring and commercial relationships need time to establish and would not have been implementable in the beginning of the privatization procedure (see Schuster (2009), p. 126).

4.2.3 Water Network

Water networks with navigable canals were the first transportation networks created around 2200 B.C. (the Shatt-el-hai, linking the rivers Tigris and Euphrat, see Galil, Nehring, Panov (2007), p. 59). Water networks include inland waterways, inter-oceanic canals (the Suez Canal and the Panama Canal) and ports (see Galil, Nehring, Panov (2007), p. 59). Based on an increasing world trade, waterway networks and ports as exchange nodes will see increasing importance in the coming years (Comtois, Slack, Sletmo (1997), p. 257).

Ships are the transporting vehicles, the service is the transport of goods and passengers. Fishing and fishing ships are excluded since they do not provide transport services. While transport vessels are also an adjunct service and thus are at least considered in the discussion, fishing ships are not.

4.2.3.1 Network Structure

Water networks are undirected networks. Ports are the nodes. They can be classified into big ports and secondary ports or differentiated whether containers are exchanged or not (for a detailed analysis of different ports, see Comtois, Slack, Sletmo ((1997), p. 258pp). Waterways and routes in the sea are the edges. Here as well traffic controls exists, but mostly to a limited extent. Europe supports an extensive waterway network of more than 28,000 km of inland waterways (see Galil, Nehring, Panov (2007), p. 60).

Network Effects

There are direct network effects for great ships and huge ports. The better the system of waterways and ports, the more flexible and thus efficient is the water transport system. Indirect network effects regarding scale effects exist for huge transport ships as well as for small traveling and leisure ships.

Complementarity and Standards

Container ships are the main reference to profit from standardization in sizes. Waterways, specifically built, can only be used by ships of a certain size.

The more standardized the ships are, the easier it is to un- and reload containers with goods. Thus, minimizing time delays and reducing cots.

Switching Costs and Lock-In

There are no real switching costs. Switching costs might be imposed when ships or transport companies have contracts with ports and want to switch ports. But there are only several competing ports worldwide, which function as hubs for smaller ports. Nevertheless, the introduction of container ports, the standardized container size imposed switching costs for ships and especially for ports. Increased ship sizes might not be serve-able by every port.

4.2.3.2 Assessment of Competitiveness

Subadditivity

There is subadditivity in terms of ports and waterways. Duplication is expensive for ports and even more expensive for waterways (see e.g. Clark et al. (2004), p. 423). Today capacity constraints are prevalent in big container ports. Duplication would only be successful and supporting competition if the competing port was as big as the duplicated harbor and thus offered the same flexibility (see e.g. Clark et al. (2004), p. 422).

Contestability

Ports are not contestable. Building a port or a new waterway is expensive and takes time. The entry lag is high and the price adjustment lag low. Additionally, ports might increase their capacity instead of allowing other ports to be established or built.

Sustainability

There are sustainability problems of container boards based on topics of an increased global production and trade.

4.2.3.3 Regulation

Yet, no conclusive details whether private or public ownership in ports leads to better efficiency were determined. But there are indicators, that privatized ports handle containers more effective (see Tongzon, Heng,(2005), p. 420). In the UK the port-business is completely privatized and concessions are awarded from the port authorities (Heaver (2006), p. 27). Full privatization of ports without liberalization was not found to be the most effective combination as Tongzon, Heng ((2005), p. 420) found in there study.

Usually ports impose tariffs for using its infrastructure. These tariffs could have regulatory mechanisms, but, as Trujillo and Nombela (1999) argue, the most important factors for shippers are the cargo-charges and the frequency of the regular services and the existence of charter services to special shipments , so that the tariff only impose a small post in the accounting, at least in areas without fierce competitors (see Trujillo, Nombela (1999), p.37f). Most ports have a so called landlord model, where the public gives the licenses to port operators (see Trujillo, Nombela (1999),p. 39), so that here again regulation is imposed within the concession contracts via a price-cap or more preferably a rate-of-return-regulation (see Trujillo, Nombela (1999),p.40), equally the concept of road concessions.

4.2.4 Rail Network

The liberalization of rail networks seems to be of high complexity based on several negative outcome examples, while in telecommunication and electricity liberalization lead to higher quality and lower prices in most cases. In my definition only rail tracks, stations and the operating system are part of the network. Trains and their services as well as construction and suppliers of different services are not included. They are using the network because they are selling services based on the network; I still mention them in our analysis.

4.2.4.1 Network Structure

The rail network is an undirected network with the stations as nodes and the tracks as edges. In addition, there has to be an operating system for the usage of tracks and stations (see e.g. Benmelech, (2009), p. 1546)

Network Effects

Based on the high capacities and fixed costs there are high positive network effects caused by additional users and expansions of the network. Passages between A and B are constructed only with a reasonable amount of transport (passengers and goods). So the more customers are requesting the transport service, the more worthwhile it is to install the track. In many countries, governments became the owners of rail companies to support economic growth and meet economic demand. Otherwise too many regions would be excluded from economic life (Vickermann (2004), p. 177).

Furthermore, there are system network effects, based on the fact that the more places are connected within the system, the more varied individual passages are and the more transports are requested. One additional station does not only lead to one new connection but to several possible combinations (see Economides (1996)).

Complementarity and Standards

Complementarities and standards are important in rail networks. As different widths of gauges force relocation of the whole train to a compatible width and different electricity standards to power engines require an exchange of the engines when crossing borders, complementarities and standardization avoid wasting time. However, different track gauges and electricity standards for engines are still prevalent within the European Union and used to be prevalent in the US beginning in the 1880s (see e.g. Benmelech, (2009), p. 1549).

Switching Costs and Lock-In

Based on the high fixed and sunk costs within the network, any change causing trains, engines and/or tracks to be replaced or upgraded results in high investment costs. It was a common strategy of competing rail companies to impose gauge sizes different from their competitors', thereby enforcing stops and trade in specific cities and preventing efficient rail trade (see e.g. Benmelech, (2009), p. 1550).

As the containers and equipment used today are usually easy to exchange, customers can use any operator offering cheaper prices.

4.2.4.2 Assessment of Competitiveness

While the network hardly seems to be competitive, there is competition between different train companies serving the same passage. There is almost no competition between tracks or stations.

Subadditivity

There is a clear subadditivity of tracks of a concrete passage. Duplication could be reasonable in cases of constraint capacity. But even in these cases there might be the problem of the fastest and cheapest passage already being covered by the incumbent so that a competing track route might not be able to compete in costs.

Likewise there is a clear subadditivity of stations. There is no sense in having several stations within a small circuit, depending on the train system. An additional competing nearby station, contracting a train for an additional stop would increase travelling times.

The operation of the system is subadditive, several competing operators would prevent an effective use of tracks and stations. Although not included in our definition of infrastructure, trains can be competing. If they have access to the network, they can compete on price and quality. There is no need for one company to serve the whole market.

Contestability

Tracks are not contestable. The construction of new passages takes time and is expensive. The tracks can hardly be used on another market. Thus the entry lag is high, and the price adjustment lag for the incumbent is low.

The stations are not contestable. The construction of new stations is expensive and takes time. Although stations are being turned into malls for travelers, their use is based on their proximity to the traveler; a second station faces high real estate costs to be able to compete. In addition, the entry lag is high and the price adjustment lag for the incumbent low.

The operation of the system is not contestable. An implementation of another operating system is not possible within the existing system.

Trains are contestable, and there also is a secondary market for transport. If one passage turns out to be inefficient, the train or parts can be used on another route. The entry lag is small, as is the price adjustment lag.

Sustainability

Currently, most of the passages are sustainable, and there is still capacity available.

There are requests for additional transport stations close to or in plants to be able to use transport routes more efficiently. Additional traveling stations might become important in areas without existing stations. Most train stations still offer capacity. But to avoid unnecessary time consuming distortion, the duplication of stations in close proximity would not improve the network but decrease availability, speed, connectivity and thus quality. It mostly would be more efficient to expand an existing station than to construct a new one.

4.2.4.3 Regulation

In rail transport there has been an increasing liberalization of the infrastructure: the infrastructure and the operation of the services have been separated in most European countries. Independent regulatory institutions have been installed and third parties have access to the infrastructure for granted fees (see Friebel et al. (2003), p.1 ff). In his paper Friebel et al. surveyed the efficiency of the railways after the liberalizations and find, that when the unbundling, the introduction of a regulatory institution and the access to third parties evolves step by step, they do increase efficiency. They point out that vertical separation is the most important part in the liberalization process (see Friebel et al. (2003), p.4)

4.2.5 Summary of Findings in Transport

Road systems are clearly natural monopolies, as well as lighting systems or parking lots in densely populated areas. But these monopolies are restricted to a local area, and the road transport system competes with the other transporting systems. In addition to the monopolistic structures, road transport is competing for surface in densely populated areas where transportation is of special importance (see e.g. Verhoef et al. (1994), p. 276).

Airports are clear natural monopolies on a local basis, as is air traffic control (Klingenberg, Klingelhöfer (2004), p. 105). But nevertheless, air traffic is competing with all different types of transport services too. From an international perspective, airport hubs are competing against each other.

Waterways and ports are natural monopolies on a local level competing with each other on a global level. They are also competing with other transport networks offering their services.

While tracks, stations and the operation system are clearly natural monopolies, services, such as train transport, can be in competition. This is in accordance with the findings of Friebel et al.(2003) who see efficiency gains in the European railway sectors especially when operation and infrastructure ownership are vertically separated and thus third parties have access to the infrastructure to offer services.

The short paragraphs on regulations show, that competitive environments can be created, when privatization and regulation enhances each other and is introduced in a careful manner. Nevertheless, regulation and monitoring still is of utmost importance within these markets to prevent anti competitive behavior.

4.3 Energy

The energy sector can be differentiated into oil and gas, two primary energy carriers, based on a physical network and electricity. The electricity network is composed of a distribution system for the transport of electricity flows, which are generated in different types of power plants, using different types of energy generation (see e.g. Viscusi, Harrington, Vernon (2005), p. 454). In the following I treat electricity separately from oil and gas.

Energy is the main driver of industrialization: appropriate lighting allows working times at night, electricity supports the concept of assembly lines and thus mass production, oil in the form of petrol is the main energy carrier in transport. Global production, enhanced by telecommunication, using electricity for transmission and translation of signals enables decentralized production and the use of export opportunities.

4.3.1 Electricity

While in telecommunication several obvious technological changes occurred within the last century, technology in electricity does not seem to have altered in the view of consumers. This is true although the liberalization of markets in all OECD countries created the possibility to choose between different suppliers and led to decreased prices (e.g. Müsgens (2006), p. 471; Joskow (1997), p. 120). A closer look reveals additional changes in the generation of electricity (for example solar and wind technologies), technological improvements in transmission networks as well as shifted consumers demands for decreased prices, sustainable electricity generation or minimally visible transmission (see Reiss, White (2008)).

4.3.1.1 Network Structure

The electricity market can be differentiated into the sub-sectors of electricity generation, the transmission grid (transformation stations, national, regional and local grids), the system operator and the retailer (see e.g. Brunekreeft, Keller (2000); Growitsch, Wein (2004), p. 29). The network is a directed out-tree network. Electricity generating plants, employing different primary energy carriers such as gas, oil, nuclear power, biomass, solar, wind or water, generate electricity (see Growitsch, Wein (2004), p. 29). The electricity is fed into the national grid, using transformation stations to adjust potential differences and electric current as well as alternating power, distributed to the regional and local grids and finally, to the consumers. The electricity is traded and sold mostly on electricity spot markets. The network structure requires high sunk cost investments. While there are additional operating costs for plants depending on the energy carriers used, the transmission grid can face high maintenance costs (see Joskow (1997), p. 123pp).

Network Effects

There are no direct positive network effects of an additional consumer using the network towards the existing consumers, as is the case in the telecommunications industry. However, due to the high sunk costs of the electricity generation and the grid, the more consumers and producers participate in the network, the lower are the costs for every single user.

Furthermore, so-called system-based network effects are immanent. This means that whenever electricity is transmitted to the consumer, there are opportunity costs which affect all other parts of the network. This is based on the fact that electricity avoids resistance and thus does not flow the shortest way but the one with the smallest resistance. The resistance is dependent on the inputs and outputs within the networks. These externalities can be positive or negative (see Knieps (2007), p. 4), but any agent in the system affects the whole system (see Estache (2004), p. 229). Innovative end devices and innovative energy generation are more advantageous when all use complementary standards and products do not have to be adapted to different systems of tension in different grids.

Complementarity and Standards

As investments in plants, transmission grids and the operation of the networks face high sunk costs and serve many consumers, it is beneficial to have complementary standards. This is also true for end devices powered by electricity. Within countries and today also within the EU, electricity has complementary standards, so that end devices and network parts can be used likewise in most countries.

Switching Costs and Lock-In

Switching costs for consumers are usually low because, at least within countries, electricity is standardized. Thus, switching the retailer does not incur any costs to the consumers regarding their end devices.

In contrast, the switching costs within the system can be high (see Joskow (1997), p. 121pp). Small changes can cause the whole system to require high investments of sunk costs. An actual example can be seen in the German exit from nuclear energy generation (see Nestle (2012)). While nuclear plants are located close to the consuming markets, renewable energy, the favored substitute, is generated in the North Sea or the mountains, creating the need for long-distance transmission networks. In addition, based on the volatile electricity generation of renewable energy, facilities to store the energy have to be constructed to balance demand with supply (currently pumped storage plants are the only available technological option). This move to new types of energy requires high investments in new structures.

Different standards between countries impede international competition of power generation, the sale of the electricity in neighboring countries and in end devices.

4.3.1.2 Assessment of Competitiveness

Historically, electricity generation, transmission and distribution in the United States was operated as a natural monopoly, exploiting high fixed and sunk costs (see Zhang (2007), p. 399).

At the beginning of the 1990s most states in the US liberalized the markets for generation, transmission and distribution, the latter two being regulated (e.g. Green (1999), p. 107; Bushnell, Mansur, Saravia (2008), p. 240).

But the severe outages in California and the Northeast in 2001 were said to be caused by this restructuring (e.g. van Doren, Taylor (2004); Zhang (2007), p. 398). The effects in detail are still under survey. In the following part, I discuss, whether the different sub-sectors show characteristics of natural monopolies. I focus on each of the sub-sectors separately.

Subadditivity

As it is already prevalent in the markets, power generation is usually provided by several companies using different energy carriers (see Growtisch, Wein (2004), p. 30). Although almost every type of power generation is based on high sunk costs, it is not advantageous for one company to produce all electricity; therefore, it is not subadditive, contestable and sustainable.

The transmission grid (national, regional and local) faces high sunk and fixed costs. Since the operation system is necessary to avoid fall-outs and to balance demand and supply, it is beneficial for one company to serve the whole market. The operating system is closely connected to the transmission grid.

The retailer is able to buy and sell electricity in competition. There is no need for one to provide all because almost no sunk or fixed costs exist.

Contestability

The power generation is contestable, as free market entry is given for power generation. There are a multitude of power plants (see Growtisch, Wein (2004), p. 30), and new types of power generation are accessing the market regularly. Wind and solar energy, for example, tend to be common now, and new types of biomass exploitation are increasing, even though the construction takes time and the price adjustment lag is fast.

Constructing new transmission grids takes time, they need to be connected to the other grids, while the price adjustment lag of the incumbent is short and operating prices are low (see Growtisch, Wein (2004), p. 33).

Operating the system is not contestable. Based on the network system externalities, a second operator within one network will create fall-outs based on a higher complexity and rivalry in balancing demand and supply (see Estache (2004), p. 229). Reserve capacities might establish competition for the field and not in the field, so it can be said to be a natural monopoly (see Growtisch, Wein (2004), p. 32).

Market entry is only possible with a new competing grid (which takes time to construct and thus has a high entry lag) and a short price adjustment lag of the operator. There is no severe price adjustment lag in the retail sector. Market entrance and exit is almost costless with no time lag.

Sustainability

Since there is already competition in the market of power generation, additional demand can be met by new market entrants.

A higher demand for transmission might impose a parallel network with parallel transformation stations, which might be competing with the first one, using different routes. But even this system has to be linked to the first network. A higher demand and supply of electricity requires more operation, but a second operation system impedes the best balancing.

Moreover, a duplication of the network is only advantageous when capacity constraints are met or new needs for sustainable energies are discussed. For Germany, the use of rail-electricity networks might be a competing force, although competition might not lead to lower prices of transmission.

As the assessment shows, there is competition in power generation and retail. The operation and regulation and the balancing of demand and supply can hardly be met by competing operators.

4.3.2 Oil and Gas

The infrastructure sector of oil and gas consists of crude oil and natural gas networks (In the following I refer to those for simplicity as 'oil and gas'. Trading of commodities on financial spot markets is not included in my analyses.).

The oil and gas infrastructure covers the physical structure of extraction, refining and transport of the commodities and is separated from the commodity trading on financial spot markets (see, for example, Knieps (2007)). The market for retail distribution of gas, oil and related byproducts such as petrol is not subject to our analysis although frequently discussed by economists (see, for example, Hubbard (2008)). Both oil and gas are treated together here, equally to other publications, because their technological structure from drilling, extraction, transmission and distribution is quite similar and one commodity is often found in conjunction with the other one (see Viscusi, Harrington and Vernon (2005), p. 671).

From a macroeconomic perspective, infrastructure projects in the natural resources sector have a large environmental impact (see e.g. Idemudia (2009)). Extraction facilities and pipelines often need to be built in remote areas which experience a loss of biodiversity through the development of land. In the course of extraction and transport, oil or gas often leaks having a large impact on flora and fauna. This is magnified by the often geographically large size of such projects. The health of the people in the surrounding area might also be affected in addition to the distortion of the social structure of their communities.

Aside from the environmental and social impact, infrastructure projects in the oil and gas sector are often politically sensitive. One reason is that many countries in Europe, the United States, but also China or Japan, are heavily dependent on commodity imports from a few commodity exporting countries, which makes their energy supply little diversified. The commodity export in turn often means a major stream of income for the exporting countries.

4.3.2.1 Network Structure

Oil and gas networks are directed in-tree networks (see Knieps (2007), p. 95). This implies that the infrastructure networks for both commodities transport the flows from a root node to an end node.

In general, the oil and gas industry differentiates between up-, mid-, and downstream segments. Extraction facilities are called the upstream sector and are root nodes in infrastructure networks, if the oil or gas commodity is passed on unchanged to the transmission network, the so-called midstream sector. Both commodities, oil and gas, are usually transported via pipeline systems. In the context of the graph theory, they represent the edge and typically transport the liquid oil or gas representing the flows.

The root node is the point of extraction of the commodity and thus considered part of the infrastructure network, since the flows are homogeneous goods from the point of extraction to the pipelines. Both crude oil and gas are often modified chemically or physically in a refinery; these flows are not homogeneous to the flows at the point of extraction and thus are not part of the network anymore. This creates a preceding network with different transported flows (A stylized example for a preceding network is the extraction and transport of crude oil. The oil is modified to a different chemical form of petroleum at an oil refinery, which serves as a root node for the ongoing infrastructure network that transports the petroleum across the country). The refinery modifies the flows and constitutes the root node of the preceding network.

The end nodes of this preceding network can be harbors or power plants. Since oil and gas can be stored, storage terminals can be considered nodes within the infrastructure network. The downstream network, which includes retail distribution, is succeeding to the long-distance transmission network and not part of the infrastructure network, if the form of the flow changes in between. Gas, for example, is typically liquefied before being transported by ship. This shows that commodities are often not transported as homogeneous goods between their point of extraction and consumption (see Knieps (2007), p. 95). The associated infrastructure network, according to our definition, is therefore a subset of the associated facilities.

Network Effects

Because the utility of the receiver is independent of the number of nodes or suppliers in these networks, no direct positive consumption effects are present as is the case in the telecommunication networks. Based on the high fixed and sunk costs it is straightforward that the network is only constructed when a threshold of enough paying consumers is interested, so they do exhibit indirect network effects.

Nevertheless, natural resources networks exhibit strong external effects, since this sector is of high importance to the economy as a whole: the commodities are used to generate electric power and, more importantly, to generate heat and fuel engines. Especially the oil product petroleum is the most important energy supplier in the transportation sector. In the United States, 95% of the total energy consumption of the transportation sector and 40% of energy consumption for the whole economy is supplied by petroleum (see Grigg (2010), p. 121pp).

Complementarity and Standards

As is the case for other networks, standards are necessary for natural resource networks to be compatible to each other. This is mostly the case for the caliber of the pipes, so that edges and nodes match physically, but also that the right pressure in the network system ensures a continuous flow. Another issue is the compatibility of the flow to the devices of the consumer (For example, a diesel engine would be damaged when fueled with benzine.) and quality, physical and chemical characteristics of the product.

Switching Costs and Lock-In

The large size and capital intensity as well as long life spans of the natural resources networks imply high switching costs and lock-in for the operator of such networks. Competition is also limited since the geographical availability of commodities is limited. This is even more the case if the rights of extraction are controlled by the same entity that controls the transmission lines. In contrast, as Viscusi et al. (2005) point out, there exists competition between the energy sources oil vs. gas vs. renewable energy etc.

4.3.2.2 Assessment of Competitiveness

There is often a regulation for the up-, mid-, and downstream sectors in the oil and gas industry. Although it can vary if the regulatory authority is on a state or federal level, this fact limits the competition in all sectors (For example, short-distance gas transmission is mainly regulated on a state level, whereas long-distance gas transmission is regulated on a federal level (see Viscusi et al. (2005), p. 674). Especially imports from other countries are affected, be it to secure national independence from energy imports or to benefit domestic energy companies (see Viscusi et al. (2005) p. 659). Apart from this, there is also an inherent competition between the means of transportation (pipeline vs. truck or ship) as well as the type of energy resource (oil vs. gas. vs. other energy carriers).

Subadditivity

In oil and gas extraction high fixed and sunk costs are prevalent for each extraction process. Especially the extraction methods from more pristine regions such as deep water and oil sand fields are technology-intensive. This can make the nodes in oil and gas networks similar capital-intensive and thus subadditive for low variable and average costs. But based on the fact that oil and gas are extracted in different regions and in competition, they are not subadditive and thus competing. The technological intensity in oil and gas transmission networks is limited compared to the telecommunication sector. They face large fixed and sunk costs with relatively small variable costs and thus average costs. This leads to a high degree of subadditivity of transmission networks (see Viscusi, Harrington, Vernon (2005), p. 672).

Contestability

Due to high fixed and sunk costs there are large entry lags which constrict contestability. The market of transmission networks is not a sustainable market as long as they can accommodate higher demand by increasing the through-flow.

Sustainability

Once the transmission networks have reached their capacity constraints and demand is sufficiently high, sustainability is given: an entrant can enter and operate profitably in the market. In gas and oil, extraction and retailing are not subadditive, but contestable and sustainable. Transmission and storage, by contrast, are subadditive. Due to high fixed and sunk costs they have a high implementation lag, while the price adjustment lag is small.

4.3.3 Regulation in Energy

In order to reach the EU's goals to reduce CO_2 and GHGs, several legislature packages were introduced (Cossent et al. (2009), p. 1145). The reforms and liberalization of the electricity sectors started in Chile (1982), United Kingdom (1991) followed by Norway (1991) (see e.g. Pollitt (2008), p. 65). The electricity distribution is usually controlled by pricing and access regulations, as well as on the quality of service and energy losses (Cossent et al. (2009), p. 1147), while the rate-of-return regulation used to be the tool of choice. Today more complex schemes to promote efficient distributions are supported and especially vertical unbundling is enforced (Pollitt (2012), p.3).

In the gas market liberalization started in the 1980s. State owned enterprises were privatized and equally vertically unbundeled to create competitive retail and wholesale markets worldwide. Only the the middle east did not follow this development (Pollitt (2012), p.3).

4.4 Water

Water is the most important resource in the world, used for many economical and ecological means, but it is of capital importance for any form of life on earth (see Clausen, Rothgang (2004), p. 163). Even though water seems abundant on the blue planet, potable water is rather scarce (see e.g. Nwankwo, Phillips, Tracey (2007), p.93). Water has to satisfy special standards with regard to purity for its different purposes. Growing populations and severe droughts, increased demand for food and contamination of sweet water resources are a threat to health and survival in several areas of the world. Desalinization and waste-water decontamination face growing importance to secure steady and sufficient water supply. But most importantly, there is no good to substitute water (see Groenewegen, Künneke, Auger (2009), p. 41). Waste-water collection and processing have been the main causes for higher hygienic standards and decreasing diseases based on polluted water so that studies find a strong correlation of access to potable water and childhood mortality and life expectancy (e.g. Galiani, Gertler, Schargrodsky (2004)). In most countries, freshwater and waste-water are processed separately even though they are both part of the same circular system (see Clausen, Rothgang (2004), p. 156). Additionally, water and wastewater treatment is provided in a local, decentralized system (see Groenewegen, Künneke, Auger (2009), p. 40). This leads to several problems based on non-internalized external effects of polluters to hygienic standards in water treatment (e.g. Easter, Rosegrant, Dinar (1999)).

4.4.1 Network Structure

The network structure of water and waste-water are directed. Water exploitation and supply are a directed in-tree, starting in the node with fresh water procurement, the transportation via pipelines, the edges, and finally the delivery to the consumers, the end nodes. The waste-water system is the corresponding out-tree, collecting the waste-water from the consumers and transporting it via pipelines to clarification plants. Different types of water procurement are accessible – desalination plants, clarification plants and, the most common type, wells, for the exploitation of ground water or withdrawals of surface water.

Network Effects

Network effects in water are driven by the size of the projects based on its high sunk and fixed costs. Thus each additional user decreases the price the existing users have to pay for building and maintaining the network. Additionally, since water is essential for life in general and is part of a circuit flow, the pollution of water and the treatment have direct effects on freshwater and thus for its use. The development of reliable water systems in Europe lead to an increase in health, life expectancy and thus productivity (see Groenewegen, Künneke, Auger (2009), p. 40).

Complementarity and Standards

There is a need for adequate hygienic standards to ensure the non-hazardous use of water for different purposes and hygienic sustainability of the water circuit flow.

Switching Costs and Lock-In

There are only marginal switching costs, depending on the quality of the water. If a poor water quality is supplied, more expensive bottled water becomes important to sustain life. This will be more expensive due to the cost of proper bottling and transport via road, rail or even air. Thus, switching is possible for households but imposes additional costs. In cases of agricultural and industrial uses, switching costs are more severe. As a study of Easter, Rosegrant, Dinar (1999) shows, consumers in developing countries pay several traders to access their welling infrastructure. Although it is more expensive to access several networks, the reliability of the network is of eminent importance for farmers and imposes competition (see Easter, Rosegrant, Dinar (1999)).

4.4.2 Assessment of Competitiveness

Although water is supplied by many decentralized companies, each of them usually serves a region without competitors. As Beecher ((2001), p.328) states: "the water industry has and will continue to display many characteristics of monopoly".

Subadditivity

Subadditivity in the water sector is high. It is cheaper for one company to exploit all water from one source than for several small companies. Exploitation or desalination and wastewater treatment as well as the pipeline networks face high sunk costs (see Groenewegen, Knneke, Auger (2009), p. 40). Due to high sunk costs, water and waste-water treatment is based on a decentralized, local structure.

Contestability

Constructing a new water or waste-water network takes a long time, whereas the price adjustment time for the incumbent is short. Thus the system is hardly contestable. Once constructed it is expensive to deconstruct, and different usages exist.

Sustainability

There is an increasing demand for water on a global level. A change in requested agricultural products to meet meat-based diets instead of vegetarian ones increases the water consumption on a worldwide level. The withdrawal of high amounts of surface water affects agricultural competitors in the downstream of a river as well as, for example, the fish population and thus the fishing industry. The same is true for pollution of water. So while in other networks an increase in demand increases the possibility for competition, in water infrastructure the negative external effects in combination with the scarcity of water creates an even more complex situation.

4.4.3 Regulation

In the topic of water regulation especially quality is in the focus. For example the waste-water-reuse is regulated on the EU level. The guidelines typically include chemical and microbiological standards, the wastewater treatment process and irrigation techniques (see Angelakis et al. (1999), p. 2251). The water networks in England and Wales were privatized in 1989. To open up monopolies new competitors were allowed within the formerly closed areas and price caps were introduced. The results were conflicting. It seems that the producers increased the prices while the input costs decreased, increasing the financial performance of the firm without efficiency gains (see Saal, Parker (2001), p.61p).

In the US water industry public ownership still dominated in 1997, only some private competitors were on the market. The sporadic private competitors mostly face rate-of-return regulation (see e.g. Beecher (2001), p.328) .

4.5 Summary of Analysis of Sectors

In this thesis I define infrastructure as physical networks with economies of scale and scope. This definition is advantageous compared to other definitions as it allows to differentiate between social and economic infrastructure, between networks and services and to integrate new networks and determinants. Thus for each sector the specific characteristics have been determined. Additionally the definition allows to assess whether, even though monopolistic structures are existent, have to be sustaining based on competition from other infrastructure systems, or whether an increase in demand makes the duplication of the network financially attractive.

As discussed, services on the physical structures are not included in the definition because they employ the networks but can be competing with other service providers and do not face the typical high sunk and fixed costs of the networks. The definition and differentiation allows to explore whether or not it is the network itself and its high economies of scale and scope preventing competition. All findings are displayed in Figure 7 and Figure 8.

However, the biggest advantage is the easy integration of new networks or new necessary network structures into the definition. One new development can be seen in the German change towards a more decentralized system in electricity generation, based on sustainable energy carriers instead of central nuclear power plants. Or the creation of an electricity mobility network, with the development of a plugging system also available in the cities without private garages. Another type of infrastructure is an underground waste transport system, connecting households directly

			Networks				Competition				
			Network Structure	Network Effects	Compatibility & Standards	Lock in & Switching Costs	Subadditivity	No (local) Subadditivity	Contestability (time lag secondary market)	Sustainability (present capacity constraint)	Competitors
Communication											
	Landline		**undirected**	positive	**y**	**y**					mobile/ cable
		lines	edge				y	n	n	y	
		joints	node				y	n	n	y	
		operator	node				n	y	y	y	
		end device	node				n	y	y	y	
	Mobile		**undirected**	positive	**y**	**y**					landline/ cable
		frequency	edge				y	n	y	y	
		terminals	node				n	y	y	y	
		operator	node				n	y	y	y	
		end device	node				n	y	y	y	
	Broadcast		**directed OUT**	positive based on economies of scale	**y**	**y**					mobile/ landline
		frequency	edge				y	n	y	y	
		lines	edge				n	y	y	y	
		broadcast	node				n	y	y	y	
		end device	node								
Energy											
	Electricity		**directed IN**	positive based on economies of scale; systemimmanent (positive and negative)	**y**	**y**					Oil /gas
		power generation	node				n	y	y	y	
		transmission grid	edge				y	n	n	y/n	
		relay station	node				y	n	n	y/n	
		retailer					n	y	y	y	
		end device	node				n	y	y	y	
		system operator					y	n	n	n	
	Oil		**directed IN**	positive based on economies of scale	**y**	**y**					electricity / gas
		drilling	node				y	n	y	y	
		pipeline	edge				y	n	n	y	
		refinery	node				n/y	y/n	y	y	
	Gas		**directed IN**	positive based on economies of scale	**y**	**y**					electricity / oil
		drilling	node				y	n	y	y	
		pipeline	edge				y	n	n	y	
		refinery	node				y	n	y	y	

Source: Own Source

FIGURE 14: Characteristics of Infrastructure Sectors (1)

with recycling plants, transporting the waste in pipelines with under-pressure. Until now, recycling plants are not systematically integrated plants, equipped by trucks, covering different regions, thus defined as social infrastructure so far. A pipeline system, using under-pressure would expand towards a network system and thus be covered by our definition, also showing indirect external network effects. All of these changed determinants or newly developed systems meet the criteria of our definition and can be analyzed with regard to network effects and competition.

The analyses of the sectors of economic infrastructure systems (existing and included

Sector	Component	Network Structure	Network Effects	Compatibility & Standards	Lock in & Switching Costs	Subadditivity	No (local) Subadditivity	Contestability (time lag secondary market)	Sustainability (present capacity constraint)	Competitors
		Networks				Competition				
Transport										
Rail		**undirected**	positive & poitive based on economies of scale	y	y					road, air, water
	station	node				y	n	n	y/n	
	track	edge				y	n	n	y/n	
	system operator	edge				y	n	n	n	
	train operator					n	y	y	y	
Road		**undirected**	positive & positive based on economies of scale	n	n					rail, air, water
	road	edge				y	n	n	y/n	
	system operator					y	n	n	n	
	vehicle					n	y	y	y	
Water		**undirected**	positive & positive based on economies of scale	n	n					rail, road, air
	ports	node				y	n	n	y/n	
	water roads	edge				y	n	n	y/n	
	system operator					y	n	n	n	
	ships					n	y	y	y	
Air		**undirected**	positive & positive based on economies of scale	n	n					rail, road, water
	airports	node				y	n	n	y/n	
	system operator	edge				y	n	n	n	
	airlines/planes					y	n	y	y	
Water		**directed IN directed OUT**	positive based on economies of scale	y	y					none
	freshwater	node				y	n	y	y	
	pipeline	edge				y	n	n	y	
	recycling	node				y	n	n	y/n	

Source: Own Source

FIGURE 15: Characteristics of Infrastructure Sectors (2)

by the definition) focused on the different sectors of infrastructure in detail. One main finding, following the work of Economides(1996), is the fact that positive, direct network effects are only found in undirected networks. Directed networks employ indirect network effects based on high fixed and sunk costs. These costs create a threshold, so that the network is only constructed if the group of people demanding the network service is big enough.

Based on the high fixed and sunk costs of the construction and the fact that the best and cheapest passage is already occupied, the duplication of the edges like pipes or roads are often not profitable so that competition is not possible. The same is true for the nodes in unregulated networks (competing airports or ports in close proximity are often not profitable and decrease the quality of the bigger central hubs). Root-nodes and end-nodes in regulated networks are competing, e.g. extraction and production of oil and gas. But the edges within the networks (pipelines) are mostly not competing, all serving the whole network.

It is worth mentioning that network effects and monopolistic structures evolve on different levels of the infrastructure. Network effects affect the whole system and influence nodes and edges and the demand for the network service or good. Competition and monopolistic structures affect different nodes and edges. While root-nodes and end-nodes are mostly competing in directed networks, the nodes between have a monopolistic structure. In undirected networks competition evolves in the nodes but not the edges.

The last point to mention are congestion problems. As the example of telecommunication shows, monopolistic structures and behavior are not necessarily sustainable. While in the beginning of 2000 nobody expected telephone lines to be congested by high data requests, the network is now competed by TV-cables, electricity cables and mobile data transfer, and still facing temporary congestion problems. Thus the sustainability of the monopolistic structure is vulnerable. The definition of infrastructure we developed is yet a theoretical idea, which still has to be tested in empirical contexts. Additionally it does not allow any predictions about the development of infrastructure or new determinants. But it gives an applicable definition for further research and discussion in the field of infrastructure.

Chapter 5

Empirical Analyses

5.1 Empirical Approach

The pivotal question of this thesis is whether private investment in firms active in infrastructure is profitable or not, whether private firms make profits and how markets assess the performance. Several specific advantages like long periods with steady cash flows are assumed, hoping to attract private investors to cover the gap in infrastructure construction, maintenance and operation. The first literature review revealed that there is no generally accepted definition for infrastructure. As a result different scientific areas treat sectors of infrastructure differently and findings are hard to compare. While Kaserer and Rothballer (2012) evaluate the systematic risk (β) with the market portfolio this part of the thesis focuses on the question whether certain characteristics of firms active in a sector of infrastructure show significant correlations with the firms' return on assets (ROA) and Tobin's Q. Therefore the proposed definition for infrastructure of chapter 3 is applied to a set of firms and tested for the different hypotheses summarized in the next chapter.

5.1.1 Summary of Hypotheses

It is of interest whether publicly listed firms in the different sectors, subsectors, active in nodes, edges or services show different results with regard to return on assets (ROA) and Tobin's Q (TQ). The theoretically oriented chapter 3 illustrates that different characteristics of the various parts of the networks should influence the performance of the firms and summarizes as follows:

- Hypothesis 1 - Monopolistic Structures
  The more firms are competing within a network, the smaller are the individual profits and thus the performance. A single firm or few firms would usually exploit prevalent monopolistic structures and ask higher prices than feasible in competitive markets. This hypothesis reflects the standard micro-economic theory, described in chapter 3.3, based e.g. on Viscusi et. al (2005).

- Hypothesis 2 - Regulation
  Regulation should impede monopolistic structures. The liberalization of the markets should increase competition and thus decrease profits and thus performance. This hypothesis is developed in chapter 3.6 and follows the research of e.g. Crew and Kleindorfer (2004), Newberry (1997) or Viscuis et al. (2005).

- Hypothesis 3 - Differing Sectors
  Often the term infrastructure refers to steady cash flows and performance, abstracting from the different sectors. But sectors differ in size, structure and properties and thus influence performance. This hypothesis is based on chapter 4 and follows the approach of Growitsch and Wein (1994).

- Hypothesis 4 - Vertical Integration
  Firms which are vertically integrated and offer services based on the network perform better than firms only active in one subsector and not offering any services. This hypothesis is developed in chapter 3.3 and is based on the research of e.g. Bühler (2004), Economides (1996), Harrington and Vernon (2005) and Tirole (1988).

- Hypothesis 5 - Direct and Indirect Network Effects
  Firms active in undirected networks do profit more from the number of existing users than firms active in directed networks. This hypothesis is developed in chapter 3.2 and refers to the research of e.g. Economides (1994), Economides and White (1994), Shaprio and Katz (1985) or Swann (2002).

To test for these hypotheses the relevant variables are introduced in the next chapter
.

5.1.2 The Empirical Model

The hypotheses developed argue that the performance of a firm depends on several factors:

- variables of the firm itself (firm specific variables);
- variables accounting for country differences (country specific variables);
- variables accounting for the sector and the country the firm is active in, specifically variables of regulation and competition (sector specific variables);

Thus the model could be summarized as:

$performance_{i,t} = \alpha + \beta_1 firm_{i,t} + \beta_2 country_{c,t} + \beta_3 sector_{s,c,t} + \epsilon_{i,t}$

where

- t indicates the year
- i indicates the firm
- s indicates the sector (or subsector)
- c indicates the country.

Performance is measured by return on assets (ROA) and Tobin's Q (TQ). The firm specific variables are for example the growth of sales, of debt, of capital expenditure as well as dividend payouts. For the analyses of Tobin's Q I vary the firm specific variables, e.g. the BookToPrice ratio is implemented and instead of dividend payouts I use the lagged value of dividend payouts.

Tabel 3 shows different variables used in the analyses. They are sorted whether they are assumed to be firm specific, country specific or sector specific. The variables and their descriptive values are displayed in the next chapters. In chapter 5.3. the empirical model is developed and tested in detail.

Table 3: Table of Empirical Variables.

Variable (abbreviation)	**Variable (long form)**	**Description**	**Calculation**	**Source**
Firm Specific Variables				
Sales	sales	Sales represents the net sales or revenues of the company converted to U.S. dollars using the fiscal year end exchange rate.		Thomson Worldscope
EBIT	earnings before interest and taxes	Earnings before interest and taxes (EBIT) represent the earnings of a company before interest expense and income taxes. It is calculated by taking the pretax income and adding back interest expense on debt and subtracting interest capitalized.		Thomson Worldscope
NetIncome	net income	Net income represents the net income of the company converted to U.S. dollars using the fiscal year end exchange rate.		Thomson Worldscope
TotDebt	total debt	Total debt represents all interest bearing and capitalized lease obligations. It is the sum of long and short term debt.		Thomson Worldscope
EntpVal	enterprise value	Market Capitalization at fiscal year end date + Preferred Stock + Minority Interest + Total Debt minus cash.		Thomson Worldscope
ComEquity	common equity	Represents the common equity of the company expressed in U.S. dollars. This item represents the common shareholders interest in the company.		Thomson Worldscope
TotAss	total assets	Total assets represent the sum of total current assets, long term receivables, investment in unconsolidated subsidiaries, other investments, net property plant and equipment and other assets.		Thomson Worldscope
PriceToBook	price to book ratio		$PriceToBook_{i,t} = (MarketPrice - High_{i,t} + MarketPrice - Low_{i,t}/2)/BookValuePerSharee_{i,t}$	Thomson Worldscope
YrEndMarketCap	year end market capitalization	Year end market capitalization represents the total market value of the company based on year end price and number of shares outstanding.		Thomson Worldscope
DivPayout	dividend payout	Dividend payout = Common Dividends (Cash)/ (Net Income before Preferred Dividends - Preferred Dividend Requirement) * 100		Thomson Worldscope
ROA	return on assets		$ROA_{i,t} = EBIT_{i,t} \ / \ TotAss_{i,t}$	Calculated value based on Thomson Worldscope
TQ	Tobin's Q		$TQ_{i,t} = TotAss_{i,t} - ComEquity_{i,t} + YrEndMarketCap_{i,t}/TotAss_{i,t}$	Calculated value based on Thomson Worldscope
BookToPrice	book to price ratio		$BookToPrice = 1/PriceToBook_{i,t}$	Calculated value based on Thomson Worldscope
Capex	capital expenditures	Capital expenditures represent the funds used to acquire fixed assets other than those associated with acquisitions. (1) Additions to property, plant and equipment (2) Investments in machinery and equipment		Thomson Worldscope

TABLE 3: Table of Empirical Variabels. (continued)

Variable (abbreviation)	**Variable (long form)**	**Description**	**Calculation**	**Source**
Sales Growth	growth of sales		$Sales_{i,t} = Sales_{i,t-1}$ / $Sales_{i,t-1}$	Calculated value based on Thomson Worldscope
DebtGrowth	growth of total debt		$TotDebt_{i,t} = TotDebt_{i,t-1}$ / $TotDebt_{i,t-1}$	Calculated value based on Thomson Worldscope
EarnDum	dummy for earnings of the pas 5 years	Earnings 5 years average = Arithmetic average of the last 5 years of Earnings Per Share / Market Price-Five Year Average Close * 100	EarnDum = 1 if earnings 5 year average > 0; 0 else	Calculated value based on Thomson Worldscope
DivDum	dummy for dividends of the past 5 years	Dividend payouts 5 year average = Sum of Common Dividends (Cash) for the last 5 years/ (Sum of Net Income before Preferred Dividends - Preferred Dividend Requirement for the last five years) * 100	DivDum = 1 if dividend payouts 5 year average > 0; 0 else	Calculated value based on Thomson Worldscope
CapexGrowth	growth of capital expenditures		$Capex_{i,t} = Capex_{i,t-1}$ / $Capex_{i,t-1}$	Calculated value based on Thomson Worldscope
EntpValGrowth	growth of enterprise value		$EntpVal_{i,t} = EntpVal_{i,t-1}$ / $EntpVal_{i,t-1}$	Calculated value based on Thomson Worldscope
EntpValToEquity	enterprise value to equity		$EntpValToEquity = EntpVal_{i,t}/ComEquity_{i,t},$	Calculated value based on Thomson Worldscope
County Specific Variables				
PopGrowth	population growth	Population growth (annual %)	$PopGrowth_{c,t} = Popul._{c,t-1}$ / $Popul._{c,t-1}$	calculated value based on UN Data
GDPPCap	gross domestic product (GDP) per capita	GDP per capita, PPP (constant 2005 international US$)		OECD Data
Sector Specific Variables				
OECD-Aggr.	index for regulation on the aggregate level	The ETCR indicators summarize regulatory provisions in seven non-manufacturing sectors: telecom., electricity, gas, post, rail, air passenger transport, and road freight.		OECD Data
OECD-Detail	index for regulation on the sector level/ sectorspecific indicator for regulation	The indicators summarize regulatory provisions in each of the seven non-manufacturing sectors: telecoms, electricity, gas, post, rail, air passenger transport, and road freight.		OECD Data
ToNumOfFirms	inverse of number of firms	The inverse of the number of firms active in the market in the specific year and sector		calculated value
HHI	Herinfahl-Index	Calculation of market power of one firm based on its total assets in contrast to the total assets of all other firms active in the market in the specific year and sector	$HHI{=}TotAss_{i,t}/\sum_{t,i,c,s}^{I} TotAss_{i,t}$	calculated value
Additional Definition				

TABLE 3: Table of Empirical Variabels. (continued)

Variable (abbreviation)	**Variable (long form)**	**Description**	**Calculation**	**Source**
ln.x	natural logarithm of a variable x		$log(x)$	

Source: Own Summary

5.2 Panel for Empirical Analyses

To test the hypotheses and apply the empirical model a comprehensive data set is built. The data set includes all infrastructure firms of 1980 to 2007 listed worldwide. For the empirical analyses firm specific, country specific and country specific as well as regulatory data over the whole period has been gathered.

The data for the empirical analyses are based on different sources described in the following paragraphs. The firm-specific data is gathered from ThomsonOne.com, the country-specific data is gathered from the OECD data base and the CIA data base, and the regulatory data is also based on the OECD regulation index. The data are panel data, covering years 1980-2007, firms and 36 countries[1]. Showing the development over this time frame the years 1980, 1993 and 2007 are chosen for comparison.

5.2.1 Country Data

The empirical set focuses on the 33 of the 34 OECD countries (excluding Island) and Brazil, China and Russia; and firms listed in these countries. The country-specific data covers the period beginning in 1980 and ending in 2007. The data is downloaded from $http://www.oecd-library.org/statistics$.

Physical economic infrastructure connects households and industry within a country and between countries. The next paragraphs will shed some light on the countries themselves and their infrastructure and the development of infrastructure for the aforementioned period.

5.2.1.1 Geographical and Demographic Characteristics

Seven of the countries are landlocked and 22 are members of the EU, for both dummy variables are created. According to an economic study on trade by Roberts

[1]The set of countries includes 33 of the 34 OECD countries (excluding Island) and Brazil, China and Russia.

and Deichmann (2009), infrastructure, especially for transport and telecommunications, benefits landlocked countries more due to growth spillovers from neighboring countries. Collier and O'Connell (2007) support this hypothesis but exclude sub-Saharan Africa in their study because of the area's lack of regional integration (see also Henckel, McKibbin (2010)).

The size of the country, its population and the density of population determine the size and dimension of infrastructure. The sample consists of unequal countries; the smallest country is Luxembourg with 2,586 km^2, and the largest is Russia with 17,098,242 km^2. It is straightforward, that the numbers of inhabitants differ between this two countries: Luxembourg had 479 thousand inhabitants in 2007, whereas Russia had 142 million inhabitants. Even though these two countries show the size at the most extreme values, Iceland, with its bigger size (103,000 km^2) shows less inhabitants than Luxembourg; the United States (301,580,000), Brazil (190,119,995) and China (1,317,885,000) have more inhabitants than Russia while also having smaller sizes of surface. All inhabitants refer to the year 2007. So the next variable to exam is the population density of these countries, equaling the relation of people per square kilometer of land area.

In 2007 the population density varied between 2.7 inhabitants per km^2 in Australia to 485.2 inhabitants per km^2 in the Netherlands. In average 120.93 inhabitants lived within one km^2 in 2007, compared to 103.85 inhabitants in 1980. In average, 25% of the urban population of the country lived in the largest city. In China with its high number of mega cities, only 2.8% of the urban population lives in the largest city in 2007. In contrast, in the country with the least inhabitants in the set, Iceland, 66.8% of the population lived 2007 in the largest city.

As the chapter of the dimensions of infrastructure has shown, population growth influences the dimension and the type of infrastructure. Population growth is caused by birth rates and immigration. The smaller a country is (like e.g. Iceland) the bigger the growth rate is for small positive changes. In average there is a positive population growth of 76.8% within 2007 for all OECD countries, which equals the average population growth within 1980. Population growth significantly differs between countries, five countries showed negative growth from 2006 to 2007 (Russia, Hungary, Estonia, Germany and Poland), but positive rates near or above 100% or even up 200% in 15 countries (France, United States, Canada, Mexico, Chile, Norway, Brazil, New Zealand, Turkey, Luxembourg, Spain, Israel, Australia, Ireland and Iceland).

The last variable to look at is population growth in cities. Analog to national population growth, the one in cities is negative in five countries (Russia, Poland, Estonia, Slovenia and Germany). Hungary shows positive population growth in cities in contrast to national population growth numbers. Within 2007, in average, cities grew more than 100%, while the highest population growth of cities could be found during that year in 2007 in Ireland. As the urban population growth rates in average during 1980 (147%) and 1993 (96%) equally are highly positive, urbanization is an important topic in this development. Infrastructures in growing cities face problems of diminishing space and increasing demand. Transport, telecommunication and energy, water supply and waste-water treatment has to be offered to an increasing number of inhabitants.

5.2.1.2 Economic Characteristics of the Countries

The gross domestic product (GDP) per capita adjusted to purchasing power parity in US$ varies considerably between the countries. In 2007, China had the lowest GDP per capita (5,238 US$), followed by Brazil (9,180 US$) and Turkey (11,973 US$). The top three countries regarding per capita income in 2007 are the United States (43,662US$) , Norway (48,799 US$), and Luxembourg (74,421US$) the highest. In average, the countries showed in 2007 a GDP per capita of 28,815 US$, which is five-fold the value of China, and 60% of the highest income in Luxembourg.

Within the period the GDP per capita increased for all countries: between 1980 and 1993 in average by 16%, between 1993 and 2007 in average by 44%, although the spread between the minimal incomes and the maximum incomes are much larger.

TABLE 4: Economic Characteristics of Countries
The data is downloaded from the OECD: *http://www.oecd-library.org/statistics*.
The set covers 36 countries, it is composed of 33 of the 34 OECD countries (excluding Island) and Brazil, China and Russia.
To highlight the development the descriptive statistics for the years 1980, 1993 and 2007 are calculated and displayed when available.

	country-Size	Pop. Dens.			Urban Pop. Growth			Pop Growth			Pop. in Large Cities (%)		
		1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007
Mean	1981549.97	103.85	111.69	120.94	1.47	0.97	1.05	0.77	0.65	0.77	25.17	24.9	24.57
Median	284525	93	96.91	100.44	1.28	0.89	0.97	0.73	0.59	0.73	22.3	22.54	21.47
Min	2586	1.91	2.3	2.74	-0.61	-2.89	-0.31	-0.51	-2.58	-0.28	3.1	2.61	2.86
Max	17098242	419.14	452.58	485.24	4.05	3.87	2.69	2.48	2.66	2.53	60.2	63.49	66.81
0.1	35902.5	10.15	11.32	12.08	0.29	-0.07	-0.04	0.1	-0.03	-0.09	8.64	8.33	7.76
0.9	1964375	229.37	241.3	299.9	3.31	2.35	1.97	1.9	1.67	1.75	46.58	46.89	43.94
St. Dev.	4065829.35	100.7	107.39	116.22	1.09	1.21	0.77	0.73	0.93	0.68	15.13	15.01	14.64
N	36	36	36	36	36	36	36	36	36	36	35	35	35

	GDP in billion US$			GDP per capita in US$			Market Cap. in US$		Value Trad. Stock in US$	
	1980	1993	2007	1980	1993	2007	1993	2007	1993	2007
Mean	596,647.22	803,730.75	1,298,137.84	17,106.78	19,895.49	28,813.53	17.01	110.74	43.8	105.13
Median	180,319.66	215,564.58	308,479.75	18,424.68	20,280.15	29,708.14	13.10	65.25	32.46	96.28
Min	4,984.69	6,380.12	11,484.34	523.95	1,507.32	5,238.68	0.26	0.04	0	8.28
Max	5,801,300.00	8,455,400.00	13,167,629.60	28,536.11	47,267.01	74,421.63	68.78	409.52	122.46	323.92
0.1	43,393.25	39,736.38	78,795.42	7,572.33	8,053.07	13,207.83	3.31	10.54	8.61	36.56
0.9	1,166,487.24	1,640,095.14	2,478,582.19	25,575.23	30,047.54	39,823.26	44.02	235.69	97.07	168.34
St. Dev.	1,090,054.25	1,508,210.68	2,451,192.56	6,838.51	9,584.52	12,962.95	16.16	106.57	35.06	68.67
N	31	36	36	31	36	36	29	36	30	36

Source: Own Calculation

Market capitalization increased by the factor 6.5, which is in line with the increasing importance of capital markets.

5.2.1.3 Infrastructure in the Countries

Chapter 2.3 has shown that infrastructure assets are correlated with economic growth, although the direction of the correlation is not determined empirically. Nevertheless this chapter will highlight the differences in infrastructure assets available, market demand and supply of the different countries and the developments over time along the different sectors.

5.2.1.3.1 Transport Sector

Total kilometers of roads are an often used variable in assessing road transport. The average distance of road kilometers increased between 1993 and 2007 from 552,050 km to 661,030 km. As to be expected the differences between the countries vary extensively, based on the variables size of country, population density and urban concentration. The country with the least km of roads is Iceland, as comparably huge country with a small and small dense population, followed by Israel and Slovenia, both, after Luxembourg, the smallest countries regarding surface size[2].

More information should be gathered by the variable road density or motor vehicles per 1,000 people. Road density varies between countries. The countries with a small road density of 6 km roads per 100 km^2 (Russia), followed by Australia with 10 km per 100 km^2 and Iceland with its 13 km per 100 km^2. In average the countries have 127.66 km per 100 km^2. Countries with a high road density are Japan (318 km^2), Netherlands (320 km^2), Belgium (501 km^2), all countries with equally a high populations density. Compared to road density, which displays the supply of infrastructure, the number of motor vehicles per 1,000 people displays the demand for transport services. In average, 44 vehicles per 1,000 people existed in 2007. In minimum 10 cars are available per 1,000 inhabitants in Estonia, followed by Sweden (11 vehicles)

[2]There are no data available for Luxembourg.

and China (12 vehicles). It is interesting to note, that none of these countries show a very small road density (in the 10% lower percentile) nor show a low total road network. The three countries with the highest numbers of cars per 1,000 inhabitants are Israel (122 vehicles), Germany (81 vehicles) and Italy (82 vehicle). As in the lower bound, neither Germany, Italy nor Israel shows a especially high road density nor a high absolute number. Equally they are not the countries with the highest GDP per capita, explaining the number of vehicles as a luxury good.

Total kilometers of rail tracks in average decreased for all countries within the period from 1980 until 2007. This is also true for the minimum and maximum value. The length of rail tracks decreases, even though rail transport is assumed to be more environmentally sustainable than road or especially air transport. This might indicate that individual traffic might have become more important since 1980. In average, compared to total road kilometers, the rail track kilometers are 30%. The small countries Luxembourg, Israel and Estonia, also have the shortest rail tracks unlike the big countries China, Russia and the United States which also show the longest rail tracks in the set.

In terms of air traffic infrastructure, it can be differentiated between airports with long and airports with short runways (data can be assessed via The World Factbook). The length of the runway influences the type of plane which can use the airport. The longer the runway is, the bigger the planes can be for landing and departure. In the United States there are 191 Airports with long runways suitable for big passenger planes and freight firms, compared to only one airport in Ireland or Iceland. Unfortunately, this data is far from being complete. Additionally approaches used to assess airports have changed over time. In Norway for example, in 2003, twelve airports had been listed, which are reclassified in 2006. A similar problem seems to have emerged for Denmark.

5.2.1.3.2 Telecommunication

Telecommunication started to be a hot topic in the 1980s. Until then landlines are the main tool for telecommunication. Internet and mobile telecommunication stated to become a market good in the 1990s. The number of telephone lines in the set in 2007 in average is 3.4 fold the number in 1980. The small countries Luxembourg and Estonia, in terms of surface, and Iceland, in terms of population density, show the lowest numbers of telephone lines. Germany, the United States and China have the most telephones lines in the set. While The United States and China have a huge surface, Germany is only in the middle regarding surface size. To compare the countries the telephone lines per 1,000 people are more relevant. The average almost doubled between 1980 and 2007. The minimum value in China increased from a low 0.21 lines per 1,000 people in 1980 and 1.47 in 1993 to only the 9th lowest value of 27.47 lines in 2007 and thus passing Mexico (with the lowest value, equaling 18.99 lines per 1,000 people), Brazil, Chile, Slovakia, Czech Republic, Turkey and Poland.

Even though mobile telecommunication is relatively uncommon in 1980, already data exists for the 35 countries in the set. In Finland only 23,482 mobile cellular subscriptions are recorded. This equals 0.49 subscriptions per 100 people. Thus each 200th person had a subscription. In 1993 in each country subscriptions are rampant, even so this equals in the maximum merely almost 9 subscriptions per 100 people in Finland, tightly followed by Sweden, Norway and Denmark. In 2007 in China, the country with the lowest subscription rate, 41,52% of the inhabitants had a subscription. In several states, like Italy, Estonia and Luxembourg, subscriptions rates are way higher than 100%.

The internet changed the way business is done in the last twenty years. After the first euphoria in the end of the nineties and the crash of the internet bubble in 1998, today the internet developed several satisfying business models. The supply and demand for internet changed likewise. In 1993 in United States, Finland, Iceland and Norway per 100 people already 2.3% of the inhabitants (the United States) up to 2.8% of the inhabitants (Norway) used the internet (equaling 120,000 people). In the lower end of the set, the countries with low GDP per capita are prevalent, showing a very low rate of internet users: China (0.0001%), Turkey (0.0084%), Russia (0.0134%), Brazil (0.0254%), Mexico (0.0284%) and Chile (0.0717%). In 2007 the picture has completely changed. In average almost 60% of the people use internet. In the lower range are still the countries with a low GDP per capita: China, (16.13%), Mexico (20.99%), Russia (24.63%), Turkey (28.63%), Brazil (30.88%) and Chile (31.02%). In contrast the northern countries (Finland, Sweden, Denmark, Netherlands, Norway and Iceland) show a high internet user rate with 80 to 90%.

The internet access via broadband highlights the pattern towards an increased use of the internet. For 1980 and 1993 no data are available. In 2007 in the countries with low GDP per capita and low internet access ratios (Russia, Brazil, Mexico, China, Turkey and Chile) the broadband access is equally low. Comparably, the countries with high access ratios also show high broadband access rations between 30% and 36% the countries include Sweden, Norway, Finland, Switzerland, Iceland, Netherlands and Denmark. This value equals 83% the average of all countries.

5.2.1.3.3 Energy Sector

Broad systematic data on infrastructure assets in the energy sector are scarce. The CIA collected data on pipelines and its length. Gas pipelines in average are the longest, followed by petrol pipelines and oil pipelines. But as the median shows, most of the countries have short pipelines. The countries with long pipelines are the United States, followed by Canada and Australia, all huge countries regarding surface and production of oil&gas, followed by Germany. Unfortunately there is no data available for Russia, one main producer and exporter for oil&gas.

The data on the consumption of the transported goods and electricity is better. The total energy consumption in mean increased from 1980 to 2007 at about 1.5. In contrast the energy consumption in kilogram of oil equivalents per 1,000 US$ GDP (in constant 2005 PPP) in average decreased. This variable indicates the energy intensity with which the GDP is generated. Thus, while the GDP increased for all countries, the energy consumption did increase at a slower rate. Especially the maximal value, produced by China, decreased from 1164.10 energy use in kilogram of oil equivalent per 1,000 US$ GDP in 1980 to 284.24 in 2007. In 2007 Russia and Iceland showed the highest energy use per GDP compared to China. Ireland, Switzerland and the United Kingdom, all countries with their main focus on financial systems show very low energy use rates.

The electric power consumption in the data set is measured in kilowatt hours per capita. In average the it increased from 1980 to 2007 by 67%. Especially the countries with a very low electricity use per capita (in 1980 China, Turkey, Mexico, Chile) increased their consumption at more than 700% (for example China). Despite the increase, in 2007 the Mexico, Brazil, Turkey and China still have the lowest electricity consumption.

The most important resource for human life is water. Unfortunately the assessment of water is equally complicated as numbers are only accessible for one or two countries.

The examples for the countries and infrastructure show that both countries and infrastructure separately are unequal in terms of size, amount, population density and wealth. Experts of various disciplines still discuss how to compare infrastructure of unequal countries. It is even more complicated to compare e.g. airports with numbers of mobile phones of different countries.

To proxy for the network size in the empirical analyses, population or population growth as well as country size will account for network effects. US$ per capita is used as a proxy for the possible network demand.

TABLE 5: Infrastructure in Numbers

The data is downloaded from the OECD. The set covers 36 countries, it is composed of 33 of the 34 OECD countries (excluding Island) and Brazil, China and Russia and covers the period 1980 – 2007. To highlight the development the descriptive statistics for the years 1980, 1993 and 2007 are calculated and displayed when available.

	Energy use per GDP per capita			Passengers carried via air transport			vehicles per km of road
	1980	1993	2007	1980	1993	2007	2007
Mean	223.99	212.97	156.59	16,830,765.25	26,341,014.33	54,717,603.76	44.00
Median	176.02	165.51	134.88	4,150,950.00	6,183,800.00	12,545,766.00	36.00
Min	85.26	106.55	83.67	161,500.00	18,300.00	651,323.00	10.00
Max	1,164.11	541.31	426.15	295,329,088.00	469,926,112.00	744,302,310.00	122.00
0.1	117.07	115.08	102.53	912,240.00	635,750.00	1,912,242.20	12.20
0.9	316.76	347.92	221.86	22,453,000.00	35,924,640.00	101,444,760.10	80.00
Std.Dev	191.88	113.98	70.48	51,725,945.42	77,902,112.29	130,363,175.24	28.65
N	30	36	36	32	36	33	22

	vehicles per 1,000 people	Total km of road			road density	Total km railtracks	
	2007	1980	1993	2007	2007	1993	2007
Mean	482.24	22,483.91	552,050.96	661,030.90	127.67	18,769.89	21,524.29
Median	537.00	7,602.75	123,759.50	144,279.00	125.00	5,885.00	8,328.50
Min	32.00	993.00	5,113.00	13,048.00	6.00	573.00	275.00
Max	820.00	265,841.94	6,284,038.00	6,489,079.00	501.00	178,104.84	226,706.00
0.1	191.20	2,006.60	41,415.00	43,306.10	13.90	1,797.80	1,435.30
0.9	685.60	40,593.20	1,035,175.20	1,242,486.40	231.60	38,945.90	52,413.00
Std.Dev	191.71	50,828.11	1,245,033.47	1,305,657.65	110.12	35,737.22	41,112.65
N	29	28	26	30	30	29	34

	% Internet-user		Telephone lines per 100 people			% broadban-daccess
	1993	2007	1980	1993	2007	2007
Mean	0.76	59.35	23.59	37.43	41.88	19.44
Median	0.40	66.05	24.80	44.09	42.35	20.44
Min	0.00	16.13	0.22	1.47	18.99	3.45
Max	2.78	89.60	58.00	67.79	65.25	35.76
0.1	0.03	29.76	4.03	11.20	22.29	5.78
0.9	2.25	83.71	41.22	57.58	58.42	31.04
Std.Dev	0.87	20.49	14.98	18.38	13.26	9.31
N	36	36	35	36	36	36

Source: Own Calculation

5.2.1.4 Private Infrastructure Investments

Data for private participation in infrastructure is increasingly available, but unfortunately only for four to maximal eight countries. For 1980 no data are available. For 1993 and 2007 data for the private participation in the sectors energy, telecommunication, transport and water and sanitation are available. For 1993 four to five countries reported and for 2007 six to eight countries are reported. The increases in average between 1993 to 2007 are high, with the lowest increase of private participation of 246% in telecommunication, followed by an increase of 448% increase in energy and 682% in transport. In water and sanitation the private investment in 1980 is very low in average at 15,200,000 current US$ and increased to 416,390,978 US$.

At a first sight the increases are higher in these sectors with low prior private participation and is lower in the sector telecommunication and energy, which are now for the longest period not considered to be complete natural monopolies any more. The data is equivalently accessible via the OECD.

5.2.1.5 Infrastructure Regulation

As private participation in infrastructure increased immensely within the last years, regulation will be part of the empirical analyses and thus the OECD indicators will be highlighted in this chapter.

The OECD regularly interviews its member states regarding their regulation in the areas of transport, post, gas, telecommunication and electricity (Conway, Nicoletti (2006), p.6, 37 describe the methodology of the ETCR indicator (it stands for energy, transport and communications) in detail I summarize here.). On the most detailed publicly available the answers of each country concerning entry barriers, state ownership, market structure as well as vertical integration of the infrastructure and services are given. On a more aggregate level, all answers are summarized on sector level, creating an index for the individual industry. In the last step all indicators of the sectors are combined in a country-specific index regarding its regulatory outcome.

The OECD data are available on a yearly basis beginning in 1975 and ending in 2007. All OECD countries are included in this survey, although for Chile, Brazil, Russia and China only data for 2007 are available. Several levels of the OECD indicator are displayed in Table 6.

Several challenges result from this measurement for the empirical analyses. It includes postal services, which for a long time have been considered a natural monopoly and infrastructure. According to the definition in this thesis, postal services are no physical economic infrastructure, but are based on the assumption of covering of specific areas as defined for social infrastructure.Air transport mainly covers airlines, which, based on the definition given in this thesis, are only providers of a service. Infrastructure of air transport is summarized in airports and air traffic control following the definition in this thesis.

As the indicators of regulation of different countries are hard to obtain and are applied very differently, the OECD aggregate is used as proxy for regulation within a country. Since the indicator at least focuses on the specific industries, it can be assumed to be a good predictor for regulatory structures.

The indicator on the aggregate level takes the values 6 0, where 6 describes the most strict environments and 0 the most liberal markets with no regulation or intervention at all. Table 6 shows the development of the indicator for different aggregate levels for the chosen years 1980, 1993 and 2007. In 1980 each level showed high regulation in average above 5 but for gas and road. The average decreases for all levels to 1993 and to 2007. In average regulation in 2007 decreased on all levels to low levels between 1.3 and 2.0. Only public ownership, indicating whether any of the infrastructure is owned and operated by public firms, in full or partly, stayed comparably high. Thus, the indicator excluding public ownership shows lower average values in 2007.

TABLE 6: Development of Regulation
The data is downloaded from the OECD: $http://www.oecd.org/eco/reform/42480163.xls$.
The set covers 36 countries, it is composed of 33 of the 34 OECD countries (excluding Island) and Brazil, China and Russia and covers the period 1980 until 2007.
For some countries in the set data is only available for some disaggregated levels, so that the number of observations vary between years and levels. To highlight the development the descriptive statistics for the years 1980, 1993 and 2007 are calculated and displayed when available. "Aggr." stands for the aggregated version of the indicator, "Aggr. without PO" indicates the aggregate indicator but excluding public ownership (PO).
Source: Conway, Nicoletti (2006)

OECD-ETCR	OECD−Aggr			OECD−aggr. without public own.			Entry barriers			Public ownership		
	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007
Mean	5.25	3.99	2.04	5.42	4.35	1.65	5.50	4.39	1.31	5.01	4.45	2.88
Median	5.42	4.20	2.00	5.61	4.33	1.49	5.65	4.39	1.27	5.20	4.60	2.98
Min	2.88	2.25	0.95	3.29	2.42	0.78	3.32	1.55	0.35	1.66	1.49	0.83
Max	6.00	5.50	3.55	6.00	5.91	3.95	6.00	6.00	3.63	6.00	6.00	4.53
0.1	4.28	2.66	1.35	4.67	3.22	0.97	4.84	3.07	0.49	3.59	2.18	1.67
0.9	5.95	5.16	2.78	6.00	5.80	2.41	6.00	5.64	1.74	6.00	5.93	3.93
St. Dev.	0.76	0.94	0.60	0.65	1.00	0.72	0.63	1.08	0.65	1.09	1.40	0.93
N	24	19	28	26	24	28	26	26	28	26	25	28

	Telecommunication			Electrcity			Gas			Rail			Road		
	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007
Mean	5.73	4.80	1.31	5.54	4.95	1.94	4.57	4.35	2.34	5.89	5.57	3.45	4.91	1.84	1.24
Median	6.00	5.86	1.24	6.00	5.50	1.64	4.95	4.60	2.15	6.00	6.00	3.75	6.00	1.12	0.98
Min	1.73	0.87	0.14	4.00	0.83	0.00	1.00	0.50	0.25	3.75	3.75	0.38	0.00	0.00	0.00
Max	6.00	6.00	2.27	6.00	6.00	6.00	6.00	6.00	4.45	6.00	6.00	6.00	6.00	6.00	5.24
0.1	5.61	1.63	0.72	4.50	4.00	0.85	2.93	2.85	0.95	6.00	4.50	2.10	0.89	0.44	0.49
0.9	6.00	6.00	2.08	6.00	6.00	3.67	6.00	5.90	3.54	6.00	6.00	4.88	6.00	3.99	2.10
St. Dev.	0.90	1.69	0.53	0.62	1.28	1.29	1.39	1.49	1.08	0.45	0.72	1.20	2.07	1.77	1.08
N	28	27	28	28	27	28	27	26	27	27	26	27	25	20	28

Source: Own Calculation

On the aggregate level in 1980 and 1993 regulations is tight in several countries bus especially in France and Slovakia. In telecommunication up to 25 countries show a rigid regulatory level of 6, equally tightly regulated is the sector rail (25 countries with an index of 6) and road (18 countries with an index of 6). These numbers indicate that regulation in 1980 is very strict. the research of Baumol, Panzar and Willig (1980) in the properties of natural monopolies, started a rethinking of regulation and markets which have to be regulated, so that the data collection of the OECD seems to be influenced by this development.

In 2007 only two sectors, each in one country inhibited tight regulations, the electricity sector in Mexico and the rail sector in Turkey. In almost all sectors deregulation lead to indicators at minimal levels between 0 and 1.8 in 2007.

5.2.1.6 A Suggestion for an Indicator to Assess Regulation

In this thesis the ETCR indicator of the OECD is used. But further developed indicator might impose several advantages. First, treating every sector separately but comparably to all other sectors makes regulation more transparent for owners, users and regulators. So the indicator for each sector should be comparable to the other indicators in every dimension such as vertical integration, public ownership, regulating agency, price controls, quantity controls and market entry barriers. This could also include other relevant factors, like the existence of a publicly owned firm or market entry regulation which could prevent competition.

Second, to avoid inter-dependencies, the number of companies in a market should be excluded in the indicator. This is based on the assumption that regulation and public ownership leads to the number of companies active in the market and is an outcome, not a cause.

Third, since networks are the basis for services vertically sold over the network, I would differentiate between the regulation of the network and the regulation of the service. As many papers on vertical integration have shown, the regulation of one part influences the outcome of the other part. To achieve this outcome, the index

Entry Regulation	
Are there regulations regarding the access to the market for new companies?	0 - no regulation 1,5 - auctioned 3 - negotiated 4,5 - regulated 6 - no access
Are there regulations regarding the access to the existing network for other companies?	0 - no regulation 1,5 - auctioned 3 - negotiated 4,5 - regulated 6 - no access
Public Ownership	
Is there a public ownership company in the market or does the government hold shares of a company?	0 - no public ownership 3 - shares 6 - only public ownership
Vertical Integration	
Are there regulations regarding vertical separation/integration of the companies?	0 - no separation 3 - accounting separation 6 - legal separation
Price Regulation	
Is there a price regulation regarding the product?	0 - no regulation 1,5 - rate of return regulation 3 - incentive regulation 4,5 - price caps 6 - governmental provision
Is there a price regulation for third-party-network access?	0 - no regulation 1,5 - rate of return regulation 3 - incentive regulation 4,5 - price caps 6 - governmental provision
Quantity Regulation	
Are there universal service obligations?	0 - no regulation 6 – regulation
Does a regulation exist to serve a specific demand for a specific price?	0 - no regulation 6 – regulation
Regulating Agency	
Is there an independent regulating agency?	0 - no agency 2 - governmental agency 4 - agency with several networks 6 - independent agency

Source: Onw Source

FIGURE 16: New Indicator for Regulation

should be computed both with and without the vertically integrated part. This suggestions are summarized in figure 16. The indicator includes entry regulation, public ownership, vertical integration, price integration, quantity regulation and the regulatory agency. This indicator is mainly based on the PLAUT-Indicator for telecommunication (see Zenhäusern et al. (2007), p. 16).

5.2.2 Firm Data

5.2.2.1 Selection of Firms

The analyses focus on publicly listed infrastructure firms. It employs a database specifically developed at the CEFS by Florian Bitsch, Christoph Jäckel, Christoph Rothballer and me for the purpose of research on infrastructure firms. Empirical analyses of the database are first published via SSRN in 2011 by Christoph Kaserer and Christoph Rothballer, cited as Rothballer and Kaserer (2012). The description of the database is based on this publication and Christoph Rothballers thesis (2012).

In a first step all Standard Industrial Classification (SIC) and Global Standard Industrial Classification (GSIC) codes relating to the infrastructure sectors are identified (Rothballer and Kaserer (2012)). All active and inactive publicly listed firms with theses codes are downloaded from Thomson Worldscope on 28 January 2010 . Downloading all firms based on their SIC and GICS codes resulted in duplicated firms but minimized the probability of excluding firms which are only labeled with one of the two codes. This resulted in 5,387 firms. Firms not applying one of the infrastructure specific codes, although active in infrastructure, are not included in the database.

In a second step all firms are examined in detail while focusing on two questions:

- Does the firm own and operate any infrastructure assets like nodes and edges?
- Is the percentage of the revenue generated by the infrastructure assets bigger than 50% of the firm's total revenue?

When both are true, the firm is added to the sample; otherwise the firm is excluded. Furthermore, we included information on whether the firm is also active in services or only owned assets and on the main field of firm's operations, resulting in a set of 2,698 firms. All this information is assessed through Thomson Worldscope and annual reports.

Again following Rothballer and Kaserer (2012), and thus Peng and Newell (2007), in a further step all funds, trusts, depository receipts and bonds are excluded, based on the information in Thomson Worldscope. These legally different types of firms are excluded because of their different financial structure. When a fund or trust for example owns an infrastructure firm they do not have to report the debt in their accounting information and thus it is harder to compare these types of firms with equity-based firms. I additionally screened the firms descriptions from Thomson Worldscope with a simple search of words and abbreviations for trusts, bonds, limited partnerships and funds, resulting in 1,491 firms.

As a result, my sample covers 36 countries within the time period 1980-2007. Ultimately, I have an unbalanced sample of 1,491 firms, covering the period from 1980 until 2007. For a more detailed description of how the data set is compiled see Rothballer and Kaserer(2012).

5.2.2.2 Market Structure

The market structure, in terms of the competitive environment, is a central point of the theoretical argumentation of infrastructure as physical networks. Thus in this chapter the market structure of the sectors of the 36 countries are displayed. Furthermore two indicators for market power are introduced, the plain inverse of number or firms in the market (ToNumOfFirms) and the Herinfahl-Indicator (HHI).

Although in the empirical analyses this work will exclude Brazil, China and Russia, the three countries are still included in the analysis of the market structure in this chapter. Within the period 1980 until 2007 the number of firms active in infrastructure sectors and listed on the world wide stock exchanges almost ten-fold from 143 firms in 1980 to 1,350 in 2007[3].

The most firms are active in the energy sector with 897 firms in 2007 (including the subsectors electricity with 291 firms and oil&gas with 606 firms). In 2007 224 firms are active in the telecommunication sector but only 120 firms (worldwide) are listed

[3]The number of observations differ from the full set, as not all firms are active in the year 2007

active in the transport sector, 72 firms in several infrastructure sectors ("multis") and only 38 firms are active in the water sector.

In the transport sector the increase in the number of firms almost 24-fold between 1980 an 2007, starting with few five firms listed in 1980. The telecommunication sector showed a fifteen-fold increase in the equivalent period and the energy sector faced an 11-fold increase of active firms. The number of firms active in several infrastructure sectors only doubled, while in the water sector the number of firms more than four-fold.

Most firms listed active in infrastructure are found in the United States (399 listed firms in 2007), followed by Canada (182 firms in 2007), China (114 firms), the United Kingdom (80 firms), Australia (75 firms) Russia (75 firms) and Brazil (56 firms). The part on descriptive statistics on the firms variables will show that the increase of firms active does not directly link to an increase in the relevant performance indicators.

TABLE 7: Number of Firms in Infrastructure Sectors
The set of infrastructure firms includes 1,491 firms owning physical infrastructure in 36 countries.

	Telecommunication			Transport			Water			Energy			Electricity			Oil /Gas			Multi			Total		
	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007
Austria	0	0	1	0	1	2	0	0	0	1	4	5	0	3	4	1	1	1	0	0	0	1	5	8
Australia	0	0	12	0	0	3	0	0	0	1	5	60	0	0	3	1	5	57	0	0	0	1	5	75
Belgium	0	1	3	0	0	0	0	0	0	1	1	6	0	0	4	1	1	2	0	0	0	1	2	9
Brazil	0	2	12	0	0	8	0	0	3	0	5	33	0	4	26	0	1	7	0	0	0	0	7	56
Canada	3	6	13	1	1	3	0	0	0	9	14	164	1	2	17	8	12	147	1	2	2	14	23	182
Chile	0	4	5	0	0	2	0	0	3	0	8	17	0	8	17	0	0	0	0	0	0	0	12	27
China	0	0	5	0	1	41	0	2	8	0	0	52	0	0	40	0	0	12	0	0	8	0	3	114
Czech Rep.	0	0	1	0	0	0	0	0	0	0	0	4	0	0	1	0	0	3	0	0	0	0	0	5
Denmark	0	1	1	0	1	1	0	0	0	0	1	3	0	1	2	0	0	1	0	0	0	0	3	5
Estland	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Finland	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2
France	1	2	7	0	2	5	0	0	1	4	10	14	1	3	7	3	7	7	1	2	2	6	16	29
Germany	1	2	4	1	4	6	0	0	0	1	2	12	1	2	4	0	0	8	5	5	8	8	13	30
United Kingdom	1	3	9	0	1	1	0	2	4	1	9	68	0	1	14	1	8	54	0	3	4	2	18	86
Greece	0	0	3	0	0	2	0	0	1	0	0	3	0	0	1	0	0	2	0	0	0	0	0	9
Hungary	0	0	2	0	0	0	0	0	0	0	0	2	0	0	1	0	0	1	0	0	0	0	0	4
Ireland	0	0	0	0	0	0	0	0	0	0	1	6	0	0	1	0	1	5	0	0	0	0	1	6
Israel	0	1	5	0	0	0	0	0	0	0	0	3	0	0	1	0	0	2	0	0	0	0	1	8
Italy	1	1	4	0	4	9	0	2	2	0	4	12	0	3	6	0	1	6	0	1	7	1	12	34
Japan	0	2	7	0	8	10	0	0	0	8	24	31	5	10	11	3	14	20	0	0	0	8	34	48
Luxemburg	0	0	3	0	0	0	0	0	0	0	2	2	0	2	2	0	0	0	0	0	0	0	2	5
Mexico	0	2	9	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	12
Netherlands	0	1	3	0	0	0	0	0	0	0	1	2	0	0	0	0	1	2	0	0	0	0	2	5
New Zeland	0	1	3	0	0	3	0	0	0	0	0	3	0	0	2	0	0	1	0	0	1	0	1	10
Norway	0	0	1	0	0	0	0	0	0	1	4	9	0	2	2	1	2	7	0	0	0	1	4	10
Poland	0	0	5	0	0	0	0	0	0	0	1	8	0	1	4	0	0	4	0	0	0	0	1	13
Portugal	0	0	3	0	0	1	0	0	0	0	0	2	0	0	1	0	0	1	0	0	1	0	0	7
Russia	0	0	14	0	0	1	0	0	0	0	0	60	0	0	41	0	0	19	0	0	0	0	0	75
Slowakia	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Spain	1	1	2	1	1	1	0	2	1	4	7	12	1	3	7	3	4	5	0	0	0	6	11	16
Rep. South Korea	0	1	9	0	0	1	0	0	0	1	4	12	1	1	1	0	3	11	0	0	0	1	5	22
Sweden	0	0	5	0	0	0	0	0	0	0	0	5	0	0	0	0	0	5	0	0	0	0	0	10
Switzerland	0	0	1	0	0	5	0	0	0	0	4	8	0	4	7	0	0	1	0	0	0	0	4	14
Turkey	0	0	2	0	0	1	0	0	0	0	2	6	0	0	4	0	2	2	0	0	1	0	2	10
United States	7	15	67	5	5	8	5	9	14	50	79	272	21	27	60	29	52	212	26	28	38	93	136	399
Total	15	46	224	8	29	119	5	17	38	82	192	897	31	77	291	51	115	606	33	41	72	143	325	1350

Source: Own Calculation

The ToNumOfFirms is the inverse of all firms counted in this sector in the specific year. Thus, when only one firm is listed, the value is 1, when two firms are listed, the value is 0.5 and so on. The correlation of this indicator is assumed to be positive. The more firms are listed within the country, the more competition should be prevalent so that the performance should be worse than in countries with only one firm or one competitor.

The second indicator for market power is the Herinfahl-Index (HHI-AssetsSubSec). The Herinfahl-Index is calculated in respect of the subsector the firm is active in. The total assets of the firm per year is divided by the sum of total assets of all firms of the subsectors per country and year. Thus, if this firm is the only firm in the market, the value again equals 1, the smaller the firms value in terms of total assets is compared to the sum of the total assets of the other firms, the smaller is the value of the HHI-AssetsSubSec ($HHI{=}TotAss_{i,t}/\sum_{t,i,c,s}^{I} TotAss_{i,t}$).

5.2.2.3 Descriptive Statistics of the Firms

The aim of this thesis is to examine whether private investments in infrastructure create profits for investors. Private investors do not construct, own or/and operate an infrastructure based on goodwill, they expect a return on their investment. In this chapter several variables to describe the firms' properties are introduced.

The descriptive statistics for the firms are given in table 8 for the years 1980, 1993 and 2007 separately. This is to display the development of the set, while the number of firms almost ten-fold in this period[4].

The variables sales, EBIT (earnings before interest and taxes), net income, total debt, the enterprise value, common equity and total assets are describing the firms properties. All are reported in million US$. Mean and maximum of the variables show an increase from 1980 to 1993 and to 2007. In contrast the median decreased for

[4]The data set has values for firms active in each of the years between 1980 and 2007. But analyses of the development of the market has shown that infrastructure industries face rapid growth in competitors, so that I hope to highlight some of the progress in the descriptive variables.

all variables from 1993 to 2007, already before the financial crises in 2008, triggered by the bankruptcy of Lehman brothers on 15th of September 2008.

This development, especially the decrease of the median of the variables sales, EBIT and net income could be a first indicator that growing competition in infrastructure, caused by firms entering the market, might not be beneficial for all firms. A growth of the standard deviation of the performance variables points towards increased disparity of firms. Rising maximal values of all variables from 1993 to 2007, accompanied by dropping minimum values further support this observation.

Variables to describe the stock markets performance of the firm are the price to book ratio, the year end market capitalization (YrEndMarketCap) and the dividends payouts. The price to book ratio increased in mean and median. Meanwhile the YrEndMarketCap increased in the mean, but decreased in the median between 1993 and 2007. Thus, more money is invested in infrastructure firms, at all and in the firm in the mean. Nevertheless the median, the better measurement for skewed distributions, shows, that the investment is not equally distributed for all firms, but favors some. The standard deviation increased for both variables. The paid dividends decreased from 1980 to 1993 and to 2007. The standard deviation only changed slightly, in 2007, its almost the value of 1980.

All these variables are assumed to have explanatory power for the performance variables. The observations of the performance variables, return on assets (ROA) and Tobin's Q both show an increase in observations. The median and mean of Tobin's Q rises between the periods. In contrast median and mean of ROA drops. In 2007 the mean is negative, while the median shows a low 5%. Accordingly the distributions are skewed. The standard deviation for ROA and Tobin's Q augments, illustrating that the increase in firms also leads to a growth in disparity.

The table 9 displays the correlations of the different variables. The correlations coefficients are calculated for the whole set and are not differentiated for single years. Return on assets and market capitalization to equity, which will be the dependent variables in the set, both show only small correlations with the explanatory variables and with each other. But the explanatory variables show high correlation with each other so that the regressions are conducted with logarithms of the variables and growth rates. In the regressions mostly logarithmic values are applied. They are illustrated in the appendix in table 20. Equally, the correlations are relatively low, especially for the two performance variables. A high correlation is found for the OECD-Agg indicator (the aggregated indicator for regulation as calculated by the OECD) and the OECD-Detail indicator for sector-specific regulation. So the both variables are usually applied in exchange and not together.

Table 8: Descriptive Statistics of Firms

	ROA			Tobin's Q		
	1980	1993	2007	1980	1993	2007
Mean	0.10	0.07	-0.11	1.01	1.35	3.10
Median	0.09	0.07	0.05	0.93	1.22	1.44
Min	-	-0.42	-18.24	0.38	0.22	0.00
Max	0.43	0.43	4.53	2.67	7.29	838.73
0.10	0.05	0.02	-0.27	0.74	0.88	0.81
0.90	0.07	0.04	-0.08	1.37	1.89	3.29
St, Dev,	0.06	0.06	0.92	0.35	0.64	26.40
N	142	295	1039	142	295	1036

	Sales in MM US$			EBIT in MM US$			NetIncome in MM US$			TotDebt in MM US$		
	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007
Mean	3,773.58	4,559.46	5,783.61	526.50	547.72	913.43	203.82	161.99	471.98	1,412.88	3,218.51	2,639.96
Median	914.09	809.17	169.85	140.31	128.37	21.89	42.66	37.18	6.94	493.67	632.40	116.58
Min	0.40	–	–	0.07	−939.25	−28,509.00	−134.42	−1,654.42	−29,580.00	–	–	–
Max	102,547.83	97,825.00	358,600.00	10,010.84	8,042.56	62,978.00	5,650.09	5,280.00	40,610.00	20,465.85	78,957.63	87,966.85
0.10	72.39	40.15	0.16	16.98	1.64	−13.53	4.12	−5.09	−23.48	39.06	12.50	–
0.90	245.27	102.27	2.57	33.52	13.13	−3.24	9.13	1.90	−4.93	89.10	62.84	0.89
St. Dev.	10,355.98	10,909.60	24,369.58	1,264.00	1,125.70	4,082.58	602.46	526.47	2,476.64	2,577.00	8,094.14	7,644.94
N	146	298	1037	143	293	1018	143	295	1038	143	293	1037

	EntpVal in MM US$			CommonEquity in MM US$			TotAss in MM US$			Capex in MM US$		
	1980	1993	2007	1980	1993	2007	1980	1993	2007	1980	1993	2007
Mean	2,967.18	7,099.78	10,564.77	1,492.80	2,259.76	3,099.13	4,557.64	8,163.81	8,990.40	534.11	674.02	833.28
Median	1,329.59	1,815.58	647.45	437.69	568.95	224.01	1,737.50	1,812.50	534.80	124.86	134.60	77.64
Min	31.13	−3.87	−129.17	0.12	−1,514.49	−7,892.00	39.54	1.97	0.02	–	–	−0.17
Max	37,478.22	150,300.84	483,587.58	25,412.64	51,566.57	132,021.39	56,576.56	112,627.88	275,644.00	7,960.97	14,983.48	27,451.22
0.10	157.81	104.88	16.22	49.96	32.42	2.79	206.80	99.80	10.44	–	–	0.24
0.90	251.54	273.79	49.07	100.65	65.52	16.77	437.32	317.21	38.43	1,437.95	1,800.44	1,903.77
St. Dev.	4,821.86	16,561.76	33,236.10	3,056.73	5,342.59	11,207.52	7,923.23	16,908.84	28,378.45	1,136.16	1,633.55	2,376.41
N	119	262	956	146	296	1038	142	295	1039	142	295	1039

	PriceToBookRatioClose			YrEndMarketCap in MM US$			DiviPayou		
	1980	1993	2007	1980	1993	2007	1980	1993	2007
Mean	1.13	2.37	3.63	1,562.40	4,591.33	7,978.73	52.89	43.73	17.84
Median	0.80	1.83	2.02	446.78	1,126.46	484.44	57.34	50.25	–
Min	0.14	−9.25	−227.79	8.33	9.10	0.20	–	–	–
Max	8.29	62.68	461.68	34,836.49	119,163.25	504,239.58	99.95	100.00	98.71
0.10	0.59	1.05	0.69	46.19	77.74	14.72	14.83	–	–
0.90	0.65	1.34	1.13	135.57	177.32	40.90	22.72	–	–
St. Dev.	1.01	4.32	22.53	3,816.49	12,255.22	28,775.14	27.04	31.96	26.84
N	128	263	963	128	263	970	123	249	941

Source: Own Calculation

TABLE 9: Correlation Matrix of Variables of the Firms

	ROA	Tobin's Q	Sales in MM US$	EBIT in MM US$	NetIncome in MM US$	TotDebt in MM US$	Capex in MM US$
ROA	1,00	-0,32	0,00	0,00	0,00	0,01	0,00
Tobin's Q	-0,32	1,00	0,00	0,00	0,00	0,00	0,00
Sales in MM US$	0,00	-0,01	1,00	0,86	0,71	0,50	0,44
EBIT in MM US$	0,00	-0,01	0,86	1,00	0,91	0,44	0,68
NetIncome in MM US$	0,00	0,00	0,71	0,91	1,00	0,21	0,79
TotDebt in MM US$	0,01	-0,01	0,50	0,44	0,21	1,00	0,24
Capex in MM US$	0,00	0,00	0,44	0,68	0,79	0,24	1,00
TotAss in MM US$	0,01	-0,01	0,82	0,70	0,47	0,80	0,34
EntpVal in MM US$	0,00	0,00	0,72	0,72	0,51	0,62	0,35
CommonEquity in MM US$	0,00	-0,01	0,77	0,63	0,43	0,52	0,24
PriceToBookRatio	0,00	0,03	0,00	0,00	0,00	0,00	0,00
YrEndMarketCap in MM US$	0,00	0,00	0,70	0,72	0,53	0,42	0,33
DiviPayou	0,02	-0,02	0,10	0,10	0,09	0,15	0,05

	TotAss in MM US$	EntpVal in MM US$	CommonEquity in MM US$	PriceToBookRatio	YrEndMarketCap in MM US$	DiviPayou
ROA	0,01	0,00	0,00	0,00	0,00	0,02
Tobin's Q	0,00	0,01	0,00	0,72	0,01	-0,01
Sales in MM US$	0,82	0,72	0,77	0,00	0,70	0,10
EBIT in MM US$	0,70	0,72	0,63	0,00	0,72	0,10
NetIncome in MM US$	0,47	0,51	0,43	0,00	0,53	0,09
TotDebt in MM US$	0,80	0,62	0,52	0,00	0,42	0,15
Capex in MM US$	0,34	0,35	0,24	0,00	0,33	0,05
TotAss in MM US$	1,00	0,80	0,87	0,00	0,69	0,14
EntpVal in MM US$	0,80	1,00	0,73	0,01	0,97	0,10
CommonEquity in MM US$	0,87	0,73	1,00	0,00	0,70	0,12
PriceToBookRatio	0,00	0,01	0,00	1,00	0,01	-0,01
YrEndMarketCap in MM US$	0,69	0,97	0,70	0,01	1,00	0,06
DiviPayou	0,14	0,10	0,12	-0,01	0,06	1,00

Source: Own Calculation

5.3 Analysis of Influence of Market Determinants and Regulation

In a first step the full unbalanced panel sample is estimated for return on assets and for Tobin's Q. Five countries are excluded from the empirical analyses because the regulatory indicators are not available for the examined period: Brazil, Chile, China, Israel, Luxembourg, Slovenia and the Republic of South Korea. With this exclusion the number of firms decreases to 1,210.

For the two dependent variables (ROA and Tobin's Q) different combinations of the independent variables of the OECD indicator (on the aggregate level or individual level of the firm's sector) are applied, as well as the two indicators to assess the market-structure in regard of competition (inverse of the number of firms in the sector of the individual country and year as well as the Herinfahl-Index (HHI). The Herinfahl-Index is calculated to assess the market power of one firm based on its total assets in contrast to the total assets of all other firms active in the market in the specific country, year and sector ($HHI{=}TotAss_{i,t}/\sum_{t,i,c,s}^{I}TotAss_{i,t})$).).

The sector specific variables are the indicators for regulation on an aggregated level (OECD-Aggr) and on a sector specific level (OECD-Detail). The detailed, sector specific indicator only considers the regulation of the specific sector. None of these indicators differentiate between the regulation of the network itself and the services offered on basis of the network.

The variables accounting for the countries' properties are population growth and GDP per capita. Both are introduced as proxies for the development of the demand side of infrastructure. A growing population reflects an increasing demand for infrastructure services, while an increase in GDP proxies for increased purchasing power of consumers. Countries with higher per capita income should not only be more interested in infrastructure services but also request more and more reliable services and goods, transported by infrastructure, thus profits should increase. This thesis also asks whether sectors (telecommunication, transport, energy (electricity and oil&gas), water and multis (multis are firms that are active in several sectors)), properties (owning nodes and edges, offering services or being completely vertically integrated) and types of networks (directed and undirected networks) show higher or lower correlations with the firms' performance. Therefore different subsets are created and regressed towards the dependent variables ROA and Tobin's Q. Additionally tests examine whether the means of the subsets differ.

For each of the full set four configuration are regressed towards the two dependent variables ROA and Tobin's Q. One configuration for each dependent variable is displayed below.

$$\mathrm{ROA}_{i,t} = ln.TotAss_{i,t} + ln.SalesGrwoth_{i,t} + ln.DebtGrowth_{i,t} + ln.CapexGrowth_{i,t} + DiviPayout_{i,t} + EarnDum_{i,t} + DivDum_{i,t} + PopGrowth_{c,t} + ln.GDPPCap_{c,t} + OECD - Aggr_{c,s,t} + HHI_{i,c,s,t}$$

and

$$\text{Tobin's Q}_{i,t} = ln.TotAss_{i,t} + ln.SalesGrwoth_{i,t} + ln.DebtGrowth_{i,t} + ln.CapexGrowth_{i,t} + BookToPrice_{i,t} + DiviPayout_{i,t} + EarnDum_{i,t} + DivDum_{i,t} + ln.PopGrowth_{c,t} + ln.GDPPCap_{c,t} + OECD - Aggr_{c,s,t} + HHI_{i,c,s,t}$$

with i= firm, t= time, c=country and s=sector.

5.3.1 Methodological Approach of Empirical Analyses

Four different empirical approaches are applied to test for the correct properties. The pooling model assumes constant intercepts and slopes for all firms (see e.g. Pindyck, Rubinstein (1998), p. 252). The random effects model introduces error terms, which are correlated across time and firms, which are assumed to be not specified in the variables (see e.g. Pindyck, Rubinstein (1998), p. 254). Two variations of the fixed effects models are estimated, for the second dummy variables for the year s are added to account that time effects exist (see e.g. Pindyck, Rubinstein (1998), p. 251).

To determine the properties of the panel set several tests are executed. First the F-Test for individual effects and the Breusch-Pagan-Test proofs the existence of individual effects, so that poolability is ruled out. Then the Breusch-Pagan-Test is conducted to test for time effects. Equally time effects are prevalent. The Hausmann-Test is conducted to differentiate between a fixed effects model and a random effects model. The fixed effects model is implemented. In several configurations and subsets the model with individual time effects proofs better than the model without. These cases are marked in the regressions and the individual time effects are listed in the appendix.

The Breusch-Godfrey/Wooldridge-Test for serial correlation in panel data models is conducted and proofs positive in most cases. The Breusch-Pagan-Test for homoskedastitcity is conducted, heteroscedasticity is prevalent in all sets (see e.g. Pindyck, Rubinfeld (1998), p. 154). All test results for all variables are displayed in the appendix, differentiating for the different panel configurations.

Problems of serial correlation and heteroskedasticity do not lead to biased or inconsistent estimators, but the estimators become inefficient (See e.g. Pindyck, Rubinstein (1998), p. 159). As serial correlation is prevalent in most and heteroskedasticity is prevalent in all panel sets, I estimate the robust covariance matrix estimation following Arellano (1987). This approach developed by Arellano allows estimations with respect to heteroskedasticity and serial correlation (Croissant, Millo (2008), p. 39).

For all configurations the variance inflation factors (VIFs) are displayed in the appendix. The VIFs quantify multicollinearity and measures how much the variance is increased by multicollinearity. Values bigger than 5 are expected to highlight severe multicollinearity. Almost all values are smaller than 2.0.

5.3.2 Return on Assets

In the first four configurations, see table 10, the explanatory variables are regressed on return on assets (ROA), the dependent variable. Adjusted R^2, the explanatory power of the model, lies between 0.053 and 0.055 and thus is low for all configurations. Nevertheless, several estimators of the robust covariance matrix estimation show significant influences on return on assets.

The correlations of the logarithm of total assets are not significant. The logarithms of sales growth show significant positive correlations in the configurations (3) and (4), and the logarithms of debt growth significant negative ones for all configurations, equally do dividend payouts. The earnings dummies exhibit significant low positive correlations. The rest of the firm specific variables do not show significant correlations.

The correlations of population growth, used as proxy for market development, are significant positive. The logarithms of GDP per capita (GDPPCap) show negative, but insignificant correlations for all four configurations.

The regulatory indicators exhibit significant negative correlations on the aggregate level (OECD-Aggr). But the correlations of sector specific indicators (OECD-Detail) for regulation are insignificant.

The variables for the competitive structure all show negative correlations. The correlations are significant on the 5% level in configurations (3) and (4) and insignificant in configurations (1) and (2).

Additionally all regressions exhibit individual time effects, all of them are negative, most are significant (the individual time effects are displayed in the appendix in table 24). These time effects might indicate, that the development of infrastructure industries do impede the performance of firms. Likewise the Herinfahl-Index (HHI) and ToNumOfFirms as well as the indicators for regulation do not map the increase of competition sufficiently.

Population growth seems to influence the ROA positively, as suggested in the hypothesis. The correlations of the GDP per capita do not support the hypothesis that higher income increase the demand for infrastructure. The hypothesis that stricter regulation leads to a decreased ROA is supported by the correlations of the aggregated indicator for regulation (OECD-Aggr), but is not supported by the ones of sector specific indicators (OECD-Detail). The hypothesis that an increase in competition decreases ROA is not supported by the correlations of the regression, all indicators for competition (HHI and ToNumOfFirms) show negative correlations.

The tests are displayed in the appendix in table 22, the variance inflation factors in table 34 and the individual time effects in table 24.

TABLE 10: Different Configurations of a Fixed Effects Model on the Dependent Variable ROA:
The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed in the appendix in table 24

	Dependent variable:			
	ROA			
	(1)$^+$	(2)$^+$	(3)$^+$	(4)$^+$
ln.TotAss	−0.003	−0.004	−0.004	−0.004
	(0.003)	(0.003)	(0.003)	(0.003)
ln.SalesGrowth	0.002	0.002	0.003**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
ln.DebtGrowth	−0.002***	−0.002**	−0.002**	−0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
ln.CapexGrowth	−0.001	−0.001	−0.0001	−0.00001
	(0.001)	(0.001)	(0.001)	(0.001)
DiviPayou	−0.0003***	−0.0003***	−0.0002***	−0.0002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
EarnDum	0.011***	0.010**	0.014***	0.014***
	(0.004)	(0.004)	(0.005)	(0.005)
DivDum	0.004	0.003	0.003	0.002
	(0.004)	(0.004)	(0.005)	(0.005)
PopGrowth	0.019***	0.020***	0.015**	0.015**
	(0.006)	(0.006)	(0.007)	(0.007)
ln.GDPPCap	−0.011	−0.007	−0.009	0.001
	(0.025)	(0.025)	(0.035)	(0.035)
OECD-Aggr	−0.007***	−0.006***		
	(0.002)	(0.002)		
OECD-Detail			0.0004	−0.001
			(0.002)	(0.002)
ToNumOfFirms	−0.002		−0.022**	
	(0.007)		(0.009)	
HHI		−0.016		−0.022**
		(0.011)		(0.011)
Observations	2,476	2,476	2,053	2,053
R^2	0.076	0.077	0.076	0.076
Adjusted R^2	0.055	0.055	0.053	0.054
F Statistic	3.977***	4.024***	3.206***	3.222***
	(df = 37; 1786)	(df = 37; 1786)	(df = 37; 1444)	(df = 37; 1444)

Note: *p<0.1; **p<0.05; ***p<0.01
$^+$Individual time effects prevalent and displayed in the appendix.
Source: Own Calculation

5.3.3 Tobin's Q

In this section the dependent variable is Tobin's Q (TQ) . Tobin's Q relates the market value of the company to its assets.

A Tobin's Q greater one indicates that the market values the firm's assets higher than the book value of assets. Thus further investments are not seen to be relevant by the market. A value smaller one indicates, that not further investments are necessary.

Again four different configurations are applied and displayed in table 11. The adjusted R^2 lies between 0.288 and 0.300 and thus the model fit is better than it is in the regressions on ROA.

For each configuration the logarithm of total assets shows a significant negative correlation with the dependent variable. For the logarithm of sales growth the correlations are significant positive, again in all four configurations. The logarithms of debt growth show a negative significant correlation, only configuration (2) exhibits an insignificant one. The correlations of the logarithm of growth of capital expenditures are not significant and negative for the configurations (1) and (4), they are positive for the configurations (2) and (3). The ones of the logarithm of the book to price ratio are significant negative for all configurations. Dividend payouts and the lagged dividends payouts show significant negative correlations. The dummy variables for dividend payouts within the last five years and positive earnings of the last five years are all insignificant.

Population growth exhibits significant positive correlations in both cases, the logarithm of population growth has a significant positive correlations on Tobin's Q in configuration (3) and a insignificant one in configuration (4). The logarithms of GDP per capita (GDPPCap) show negative correlations, and are significant on the 1% level in configuration (2) and (3).

The correlations of the aggregated indicator for regulation (OECD-Aggr) are positive but insignificant, whereas the regulatory indicators of the sectors (OECD-Detail) are significant positive on the 5% level.

The ToNumOfFirms shows insignificant positive correlations in configuration (1) and (2), whereas the Herinfahl-Index (HHI) shows negative correlations, in configuration (4) it is significant on the 1% level.

For all configurations time effects are prevalent. They are, especially since 1995, significant positive in the configurations (2), (3) and (4).

Thus again an increase in population growth increases the demand for infrastructure and increases Tobin's Q. In contrast the the GDP per capita exhibits negative, even significant correlations. Thus it might be true that in countries with higher GDP per capita less opportunities for private investments in infrastructure are prevalent. The correlations of the regulatory indicators contrast the finding of the regressions on ROA, as on Tobin's Q the correlations are positive, firms active in countries with stricter regulation exhibit a higher Tobin's Q.

The tests are displayed in the appendix in table 23, the variance inflation factors in table 34 and the individual time effects in table 25.

5.3.4 Robustness Tests

For all configurations three sets to test for robustness of the findings are created.

The first set is a handcleaned data set, where I excluded all extreme values of ROA. The second set is a calculated sub set, excluding observations with high values of total assets. The third set I created by excluding observations with high market capitalization.

In the first set I excluded values with ROA $\in [-100 < ROA > 100]$. Running all regressions, tests and the covariance matrix estimations, results are identical to the details in the main set, thus no data cleansing is introduced. This configurations and results are not displayed in the thesis, as only 18 values are excluded.

The second subset is created based on total assets. For total assets all firms are excluded having total assets
$\in [> mean(TotAss) + 2 * st.dev.(TotAss)]$.

All four configurations of each of the dependent variables are estimated. The results of regressions, tests and the covariance matrix estimator, as well as the variance inflation factors (VIFs) are displayed in the appendix.

For ROA the covariance matrix estimators are displayed in table 26, the tests in table 22, the variance inflation factors in table 35 and the individual time effects in

TABLE 11: Different Configurations of a Fixed Effects Model on the Dependent Variable Tobin's Q:
The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed in the appendix in table 25

	Dependent variable:			
	TQ			
	(1)+	(2)+	(3)+	(4)+
ln.TotAss	-0.080^{**}	-0.091^{***}	-0.103^{***}	-0.093^{***}
	(0.032)	(0.032)	(0.029)	(0.027)
ln.SalesGrowth	0.035^{***}	0.041^{***}	0.041^{***}	0.033^{***}
	(0.008)	(0.011)	(0.011)	(0.008)
ln.DebtGrowth	-0.013^{**}	-0.012	-0.014^{**}	-0.014^{**}
	(0.006)	(0.007)	(0.007)	(0.006)
ln.CapexGrowth	-0.003	0.0003	0.003	-0.002
	(0.006)	(0.007)	(0.007)	(0.006)
ln.BookToPrice	-0.653^{***}	-0.664^{***}	-0.656^{***}	-0.653^{***}
	(0.050)	(0.053)	(0.057)	(0.055)
DiviPayou	-0.001^{***}	-0.001^{**}		
	(0.0003)	(0.0004)		
lag(DiviPayou)			-0.001^{*}	-0.001^{**}
			(0.001)	(0.001)
EarnDum	0.018	0.041	0.061	0.022
	(0.037)	(0.041)	(0.048)	(0.036)
DivDum	0.005	0.007	-0.015	-0.008
	(0.018)	(0.022)	(0.027)	(0.022)
PopGrowth	0.111^{***}	0.135^{***}		
	(0.030)	(0.032)		
ln.PopGrowth			0.033^{**}	0.017
			(0.013)	(0.015)
ln.GDPPCap	-0.249	-0.405^{*}	-0.499^{*}	-0.384
	(0.234)	(0.236)	(0.257)	(0.235)
OECD-Aggr	0.009			0.020
	(0.019)			(0.018)
OECD-Detail		0.033^{**}	0.028^{**}	
		(0.013)	(0.011)	
ToNumOfFirms	0.154	0.114		
	(0.109)	(0.111)		
HHI			-0.200	-0.222^{*}
			(0.136)	(0.123)
Observations	2,133	1,730	1,667	2,066
R^2	0.419	0.422	0.420	0.422
Adjusted R^2	0.298	0.291	0.288	0.300
F Statistic	28.814^{***}	22.927^{***}	21.765^{***}	28.237^{***}
	(df = 38; 1521)	(df = 38; 1191)	(df = 38; 1140)	(df = 38; 1467)

Note: *p<0.1; **p<0.05; ***p<0.01
+Individual time effects prevalent and displayed in the appendix.
Source: Own Calculation

table 27. For Tobin's Q the covariance matrix estimators are displayed in table 28, the tests in table 23, the variance inflation factors in table 35 and the individual time effects in table 29.

Using the described algorithms to exclude outliers based on the total assets of the firm the observations per set decrease. For the panel data set testing for returns on assets 106 to 121 observations are excluded, based on the different configurations. For the regression on the dependent variable Tobin's Q between 96 to 112 observations are excluded.

The tests show the same properties of time fixed effects, heteroskedasticity and serial correlation, so that again the covariance matrices are estimated and displayed in the appendix in table 24 for ROA and in table 26 for Tobin's Q. The individual time effects are printed in table 27 for ROA and in table 29 for Tobin's Q

The adjusted R^2 decreases slightly for all configurations of the reduced subset regressed on ROA. The directions of the correlations stay unchanged for almost all variables and configurations. The correlations of the logarithms of growth of capital expenditure change from insignificant negative to insignificant positive in configuration (3) and (4). The aggregated indicators for regulation (OECD-Aggr.), which in the full set exhibit significant positive correlations on the 1% level, shows an significant positive correlation for configuration (1) on the 10% level and an insignificant one in configuration (2) for the reduced subset. Furthermore the correlation of the logarithm of GDP per capita turns from insignificant negative to insignificant positive in configuration (3). In the reduced set several correlations turn significant in contrast to the full set.

In the regressions on the dependent variable Tobin's Q the adjusted R^2 decreases for each configuration. But several insignificant variables change the direction of correlation, the significances change in three cases.

In configuration (1) the insignificant positive correlation of the logarithm of capital expenditure turns insignificant negative. This is also true for configuration (2), here the insignificant negative correlation turns significant positive on the 1% level.

The correlations of the dummy variables for dividends paid in the past five years turn from insignificant positive to insignificant negative in the configurations (1) and (2). This likewise happen to the correlations of ToNumOfFirms in these configurations.

The correlations of the logarithm of GDP per capita (GDPPCap) turn insignificant in the configurations (2) and (3). In contrast the correlation of the dummy for earnings of the past five years turns significant in configuration (3).

Equally the third subset, using market capitalization, is created. All firms are excluded having a market capitalization
$\in [> mean(marketcapitalization) + 2 * st.dev.(marketcapitalization)]$.
Here the excluded observations account for 460 to 602 for the regressions on ROA and 360 up to 552 observations for regressions on Tobin's Q.

For the performance variable ROA the reduced sets show lower adjusted R^2 than the full sets and configurations. Nevertheless, the directions of the correlations do not change, but the insignificant negative correlations of the sector specific indicators for regulation (OECD-Detail) turn insignificant positive. Additionally several correlations turn insignificant.

For all sets, subsets and configurations, the logarithms of population growth show a highly significant positive correlation with ROA. And the indicators for regulation are mostly negatively correlated, often significant. The correlations for the market power, the Herinfahl-Index (HHI) and the ToNumOfFirms, are mostly negatively correlated, but insignificant.

In the regressions on the dependent variable Tobin's Q for each configuration the adjusted R^2 decreases slightly. While in the subset with excluded observations based on total assets several insignificant variables change their direction of correlation, in this subset only some variables change their direction, but many turn insignificant.

The correlations of the logarithm of growth of capital expenditures turn from insignificant positive to insignificant negative in the configurations (2) and (3), likewise changes the earnings dummy for earnings of the past five years in configuration (4).

The correlations of the dividends dummies turn from insignificant negative to insignificant positive for the configurations (3) and (4). For dividend payouts and the logarithm of dividend payouts the correlations turn insignificant for all configurations.

Likewise the correlations of population growth and the logarithm of population growth turn insignificant in the configurations (1) and (3). The correlation of the logarithm of GDP per capita (GDPPCap) in configuration (1) turns insignificant as well as the regulatory indicators for the regulation of the sectors (OECD-Detail) in the configurations (2) and (3) do. Thus in the reduced subset no regulatory indicator is significant.

Time effects are prevalent for all configurations and are displayed in the appendix in the tables 31 and 33. But, when firms with high market capitalization are excluded, many of the individual time effects turn significant positive. This is in contrast to the subset reduced on base of total assets. Here most individual time effects are negative but insignificant, likewise to the full set.

For ROA the covariance matrix estimators are displayed in table 30, the tests in table 22, the variance inflation factors in table 36 and the individual time effects in table 31. For Tobin's Q the covariance matrix estimators are displayed in table 32, the tests in table 23, the variance inflation factors in table 36 and the individual time effects in table 33.

5.4 Analysis of Sectors

In this section for each sector a subset is created. They are regressed on ROA and Tobin's Q to examine whether the sectors differ in correlations and fit. Therefore the full set is split into the subsets telecommunication, transport, energy and multis. Multis include all firms which are active in several sectors. Additionally the sector energy is split into the subsectors electricity and oil & gas. The sector water is excluded from the analyses, because too few observations are available.

Again it is of interest whether the sector specific and country specific variables influence the performance and whether the correlations of the variables differ between sectors and subsectors.

The different empirical approaches and tests are conducted as described in chapter 5.3.1 and are displayed in table 34 for ROA and table 35 for Tobin's Q. The fixed effects model is implemented and for each sector the following regressions on the two dependent variables are conducted:

$$\text{ROA}_{i,t} = ln.TotAss_{i,t} + ln.SalesGrwoth_{i,t} + ln.DebtGrowth_{i,t} + ln.CapexGrowth_{i,t} + DiviPayout_{i,t} + EarnDum_{i,t} + DivDum_{i,t} + PopGrowth_{c,t} + ln.GDPPCap_{c,t} + OECD-Aggr_{c,s,t} + HHI_{i,c,s,t}$$

and

$$\text{Tobin's Q}_{i,t} = ln.TotAss_{i,t} + ln.SalesGrwoth_{i,t} + ln.DebtGrowth_{i,t} + ln.CapexGrowth_{i,t} + BookToPrice_{i,t}$$

$+ DiviPayout_{i,t} + EarnDum_{i,t} + DivDum_{i,t} + ln.PopGrowth_{c,t} + ln.GDPPCap_{c,t} + OECD - Aggr_{c,s,t} + HHI_{i,c,s,t}$

with i= firm, t= time, c=country and s=sector.

For the subset "‘multis" the regulatory indicator of the specific sector, OECD-Detail, is replaced with aggregated indicator OECD-Aggr.

As serial correlation and heteroskedasticity do not lead to biased or inconsistent estimators, but the estimators become inefficient (see e.g. Pindyck, Rubinstein (1998), p. 159) I estimate the robust covariance matrix estimation following Arellano (1987) with the years indicated. In several subsets the model with individual time effects proofs better than the model without. These cases are marked in the regressions and the individual time effects are again listed in the appendix.

5.4.1 Return on Assets

In the first regressions the dependent variable is return on assets, similar to the procedure of the regressions of the full set. The first two sectors are telecommunication and transport, both are (mostly) undirected networks with direct and indirect network effects. Energy, including electricity and oil & gas, are directed networks, which only have indirect network effects. Accordingly multis, includes all firms active in several sectors, have at least indirect network effects.

The adjusted R^2 is lowest for the regression of firms active in the telecommunication sector and highest for multis.

The correlations of the logarithm of total assets are significant negative for firms active in telecommunication, transport, electricity and multis. The correlations of the logarithm are insignificant negative, identical to the results of the full set, for the sector energy and its subsector oil & gas. The correlations of the logarithm of sales growth show different directions and significations: firms active in the telecommunication sector have a significant negative correlation; these active in energy and oil & gas significant positive ones and firms active in the the sectors transport, electricity and multis exhibit insignificant positive ones, likewise to the results of the full set.

The correlations of the logarithm of debt growth are negative, but only are significant for firms active in energy and its subsector of oil & gas. The correlations of the logarithm of growth of capital expenditures are insignificant, positive for firms active in telecommunication and transport, but are negative for the rest of sectors. Dividend payouts are significantly negatively correlated for all sectors but firms active in telecommunication, they exhibit an insignificant positive correlation. The dummy variables for earnings in the past five years exhibit a significant positive correlation for the sector of telecommunication, insignificant ones for firms active in energy and its subsectors electricity and oil & gas and insignificant negative ones for firms active in transport and multis. The dummy for dividends paid in the past five years show positive correlations for firms active in the sectors telecommunication, transport and energy. The correlations are significant for the firms active in electricity and multis. The correlation is insignificant and negative for firms active in the subsector oil & gas.

The variables of population growth show mostly significant positive correlations, they are insignificant for the subsets telecommunication and multis. The logarithms of GDP per capita (GDPPCap) exhibit mostly significant positive correlations, but are insignificant for the subsets of firms active in energy and multis, and it is significant negative for oil & gas.

The indicator for regulation shows insignificant positive correlations. The correlations are negative and significant for firms active in energy, electricity and multis, they are insignificant for firms active in transport and oil & gas. This implies that less regulation increases ROA.

Analogous the results of the Herinfahl-Index (HHI), calculated on total assets, are contradicting for the different sectors. Firms active in several sectors, multis, exhibit a significant positive correlation with ROA, indicating that in markets with only a few, comparably smaller firms, the performance rise. In contrast, the sector of transport shows a significant negative correlation, for firms active in the sectors telecommunication, energy, electricity and oil & gas the negative correlations are insignificant.

Individual time effects are prevalent for firms active in energy, electricity, oil & gas and multis. The individual effects almost all show a significant negative correlation. The individual time effects are displayed in the appendix in table 39.

The tests are displayed in the appendix in table 37 and the variance inflation factors in table 45.

TABLE 12: Subsets of Sectors Regressed in a Fixed Effects Model on the Dependent Variable ROA:
The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For the sector energy, electricity, oil & gas and multis individual time effects are identified and displayed in the appendix in table 39.

	Dependent variable:					
	ROA					
	(Telecomm.)	(Transport)	(Energy$^+$)	(Electricity$^+$)	(Oil& Gas$^+$)	(Multis$^+$)
ln.TotAss	-0.017^{**}	-0.030^{***}	0.003	-0.008^{**}	0.002	-0.020^{***}
	(0.007)	(0.004)	(0.002)	(0.003)	(0.003)	(0.003)
ln.SalesGrowth	-0.006^{*}	0.002	0.004^{***}	0.002	0.005^{***}	0.0004
	(0.004)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
ln.DebtGrowth	-0.003	-0.001	-0.002^{**}	-0.001	-0.003^{**}	-0.001
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
ln.CapexGrowth	0.001	0.001	-0.001	-0.0003	-0.0001	-0.001
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
DiviPayou	0.0002	-0.0003^{***}	-0.0004^{***}	-0.0002^{**}	-0.0005^{***}	-0.0002^{***}
	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
EarnDum	0.024^{**}	-0.005	0.005	0.001	0.005	-0.005
	(0.010)	(0.007)	(0.005)	(0.008)	(0.007)	(0.005)
DivDum	0.008	0.013	0.001	0.007^{*}	-0.001	0.010^{***}
	(0.009)	(0.009)	(0.005)	(0.004)	(0.007)	(0.003)
PopGrowth	0.030	0.029^{***}	0.017^{***}	0.033^{***}	0.020^{***}	0.003
	(0.021)	(0.010)	(0.005)	(0.010)	(0.007)	(0.007)
ln.GDPPCap	0.093^{*}	0.070^{**}	0.031	0.144^{**}	-0.099^{**}	0.020
	(0.049)	(0.031)	(0.033)	(0.060)	(0.047)	(0.075)
OECD-Aggr	0.002	-0.0004	-0.008^{**}	-0.013^{***}	-0.003	-0.023^{***}
	(0.007)	(0.004)	(0.004)	(0.003)	(0.006)	(0.003)
HHI	-0.003	-0.050^{**}	-0.015	-0.002	-0.011	0.078^{***}
	(0.034)	(0.024)	(0.013)	(0.014)	(0.019)	(0.027)
Observations	423	176	1,402	472	930	349
R^2	0.061	0.277	0.126	0.277	0.163	0.556
Adjusted R^2	0.041	0.182	0.088	0.185	0.109	0.402
F Statistic	1.660^{*}	4.033^{***}	3.810^{***}	3.267^{***}	3.280^{***}	8.532^{***}
	(df = 11; 280)	(df = 11; 116)	(df = 37; 975)	(df = 37; 315)	(df = 37; 623)	(df = 37; 252)

Note: *p<0.1; **p<0.05; ***p<0.01
$^{+}$Individual time effects prevalent and displayed in the appendix.
Source: Own Calculation

5.4.2 Tobin's Q

The results of the subsets of sectors regressed towards the dependent variable Tobin's Q are displayed in table 13. Adjusted R^2 is higher than in the regression of sectors on ROA and varies between 0.265 for firms active in the sector telecommunication and 0.558 for firms active in several sectors (multis).

The correlations of the logarithm of total assets are negative and significant for all sectors but firms active in the subsector oil & gas and the set of multis. The results of the logarithms of sales growth are significant positive for firms active in telecommunication, energy and oil & gas. They are insignificant for firms active in transport and multis; for the sector of electricity it is insignificant and negative. The correlations of the logarithm of debt growth are significant and negative for firms active in telecommunication and multis. For the other sectors they are insignificant and positive. The correlations of the logarithm of growth of capital expenditures are significant and positive for energy and its subsector electricity. They are insignificant and positive for firms active in transport and oil & gas and negative for firms active in telecommunication and multis. The logarithm of the book to price ratio exhibit negative and significant correlations for all sectors. Dividend payouts show significant and negative ones for all sectors but for telecommunication and multis, here the correlations are insignificant and positive. The dummy for earnings and the dummy for dividends paid in the last five years show both different correlations for the sectors.

The correlations of the logarithm of population growth, showing a significant positive correlation in the full set, exhibit for firms active in telecommunication, energy, and oil & gas again a significant positive correlation. Firms active in electricity show an insignificant positive correlation. The correlations for the sectors transport and multis are negative and insignificant.

The correlations of the logarithm of GDP per capita are significant negative for the sectors electricity and multis and insignificant for energy. The sectors telecommunication, transport and oil & gas show positive but insignificant correlations.

The indicator for regulation shows a significant negative correlation for the sector electricity, insignificant negative ones for transport, oil & gas and multis and insignificant positive ones for firms active in energy and telecommunication.

The Herinfahl-Index (HHI) exhibits negative correlations for all sectors but multis. The negative correlations are significant for telecommunication and energy. The positive correlation of firms active in several sectors (multis) is significant.

Time effects are prevalent for the sector energy, electricity and multis. They are displayed in the appendix in table 40. The time effects are positive and mostly insignificant.

The tests are displayed in the appendix in table 38 and the variance inflation factors in table 45.

5.4.3 Robustness Tests

For each sector and the subsectors electricity and oil & gas a subset is created. For each sector and the two subsectors all firms having total assets over the threshold
$\in [> mean(totalassets) + 2 * st.dev.(totalassets)]$
are excluded.

For the regressions on ROA between 13 (firms active in the sector multis) and 69 (firms active in the sector energy) are excluded.

The results of regressions, tests and the covariance matrix estimator are displayed in the appendix in chapter A.0.3. For ROA the covariance matrix estimators are displayed in table 41, the tests in table 37, the variance inflation factors in table 46 and the individual time effects in table 42. For Tobin's Q the covariance matrix estimators are displayed in table 43, the tests in table 38, the variance inflation factors in table 46 and the individual time effects in table 43.

In the regressions on ROA for firms active in the sectors transport, energy, electricity, and multis the correlations only change slightly between significant and insignificant.

TABLE 13: Subsets of Sectors Regressed in a Fixed Effects Model on the Dependent Variable Tobin's Q:
The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For the sector energy, electricity and multis individual time effects are identified and displayed in the appendix in table 40.

	Dependent variable:					
	TQ					
	(Telecomm.)	(Transport)	(Energy$^+$)	(Electricity$^+$)	(Oil& Gas)	(Multis$^+$)
ln.TotAss	-0.348^{**}	-0.087^{**}	-0.077^{***}	-0.077^{***}	-0.044	-0.003
	(0.154)	(0.038)	(0.025)	(0.026)	(0.031)	(0.023)
ln.SalesGrowth	0.079^{***}	0.012	0.036^{**}	-0.005	0.045^{***}	0.006
	(0.029)	(0.008)	(0.014)	(0.006)	(0.016)	(0.005)
ln.DebtGrowth	-0.054^{***}	-0.007	-0.005	0.006	-0.004	-0.015^{***}
	(0.020)	(0.008)	(0.008)	(0.005)	(0.011)	(0.004)
ln.CapexGrowth	-0.013	0.001	0.013^{**}	0.019^{***}	0.010	-0.005
	(0.022)	(0.011)	(0.006)	(0.007)	(0.007)	(0.003)
ln.BookToPrice	-0.771^{***}	-0.511^{***}	-0.579^{***}	-0.488^{***}	-0.640^{***}	-0.527^{***}
	(0.123)	(0.047)	(0.079)	(0.054)	(0.081)	(0.047)
lag(DiviPayou)	0.001	-0.003^{***}	-0.001^{***}	-0.001^{**}	-0.002^{***}	0.0003
	(0.002)	(0.001)	(0.0005)	(0.0003)	(0.001)	(0.0004)
EarnDum	0.014	-0.152^{***}	0.095^{*}	0.052	0.099	-0.076^{*}
	(0.059)	(0.038)	(0.051)	(0.052)	(0.061)	(0.045)
DivDum	0.041	0.097^{**}	-0.009	-0.005	-0.039	-0.002
	(0.046)	(0.037)	(0.038)	(0.019)	(0.057)	(0.032)
ln.PopGrowth	0.170^{**}	-0.010	0.040^{***}	0.002	0.041^{**}	-0.057
	(0.071)	(0.015)	(0.015)	(0.014)	(0.020)	(0.040)
ln.GDPPCap	0.864	0.213	-0.229	-0.656^{**}	0.094	-1.884^{*}
	(1.000)	(0.194)	(0.322)	(0.274)	(0.286)	(1.098)
OECD-Aggr	0.048	-0.035	0.011	-0.080^{***}	-0.021	-0.005
	(0.059)	(0.025)	(0.028)	(0.022)	(0.038)	(0.028)
HHI	-0.661^{*}	-0.013	-0.299^{**}	-0.017	-0.227	0.970^{*}
	(0.397)	(0.151)	(0.140)	(0.110)	(0.179)	(0.503)
Observations	330	150	1,153	348	805	309
R^2	0.431	0.673	0.442	0.766	0.402	0.784
Adjusted R^2	0.265	0.426	0.301	0.495	0.274	0.558
F Statistic	12.822^{***}	16.272^{***}	16.371^{***}	19.412^{***}	30.704^{***}	20.970^{***}
	(df = 12; 203)	(df = 12; 95)	(df = 38; 785)	(df = 38; 225)	(df = 12; 548)	(df = 38; 220)
Note:						*p<0.1; **p<0.05; ***p<0.01

$^+$Individual time effects prevalent and displayed in the appendix.
Source: Own Calculation

For the firms active in telecommunication the logarithm of total assets changes from a small insignificant negative value to a small insignificant positive value, as does the one of the Herinfahl-Index (HHI) does.

In the regression on ROA of the subsector oil & gas the correlations of several variables change: the correlation of the dummy of dividends paid in the past five years turns form insignificant negative to insignificant positive, as the indicator for regulation and the Herinfahl Index (HHI) both do.

In the robustness tests on the dependent variable Tobin's Q the subsets of sectors decrease by 11 (multis) up to 67 (energy). The adjusted R^2 decreases strongly for firms active in telecommunication, slightly for transport, energy, electricity and oil & gas but increases for firms active in several sectors (multis).

In the regressions of the sector of firms active in transport and energy the directions and significances of the correlations do not change. In the subset of the subsector of firms active in electricity the correlation of the logarithm of population growth turns from insignificant positive to insignificant negative.

In the subset of the subsector oil & gas the correlation of the dummy variable for earnings in the past five years turns significant and the one of the the logarithm of population growth turns insignificant.

For the subset of firms active in several sectors (multis) the correlation of the logarithm of total assets turns form insignificant negative to positive and the one of lagged dividend payouts turns from insignificant positive to negative. And while the correlation of the dummy for dividends paid in the past five years turns significant, the one of the logarithm of GDP per capita (GDPPCap) turns insignificant.

The regression on the subset of firms active in telecommunication, also showing the biggest decrease in adjusted R^2, exhibits the most changes in the direction of the independent variables on the dependent variable Tobin's Q. The correlation of the logarithm of growth of capital expenditures turns from insignificant negative to positive, the lagged dividends payouts, the dummy for dividend paid in the past five years, and the indicator for regulation turn from insignificant positive to insignificant negative. The correlations of the variables logarithm of population growth and the Herinfahl-Index (HHI) turn insignificant.

In the regressions on ROA an Tobin's Q without firms with high total assets excluded, the correlations indicated, that the dependent variables of the different sectors are influenced dissimilar. This result is supported by the robustness test. Additionally the results of some sectors react sensitively to the exclusion of firms, while others do not.

5.4.4 F-Test for Different Means of Subsets of Different Sectors

The F-test examines whether the mean of the performance variables (ROA and Tobin's Q) of the sectors differ significantly from each other.

When the variances of the performance variables of the sectors differ, the Welch-Test has to be applied. Therefore in a first step the variables of the sectors are tested for differences in the variances. The tests are displayed in the appendix in table 47 for ROA and 48 for Tobin's Q. According to the tests all sectors have different variances so that the Welch-Test is applied to each combination of variables of the sectors and presented in table 14 for ROA and 15 for Tobin's Q.

The mean of the variable ROA for the different sectors only varies significantly for the combinations of the sets electricity and transport, multis and transport and multis and electricity. For all other sets the means of the return on assets do not vary significantly. This result is equally true for the reduced subsets, based where all observations are excluded with total assets $\in [> mean(TotAss) + 2 * st.dev.(TotAss)]$. The results are displayed in the appendix in table 48.

The means of the variable Tobin's Q differ for eight pairwise combinations of sectors significantly. The mean of firms active in the transport sector differs significantly with the sectors of telecommunication, energy and multis. The mean of firms active in the water sector shows significant different means with telecommunication, energy and multis. And consequently the mean of firms active in several sectors, multis, show a significant variation to the mean of firms active in the sector of energy.

Table 14: Means of ROA of Different Sectors

Variable ROA	Data Sets 1& 2	T	DF	P-Value	95% Conf. Intv. Set 1	95% Conf. Intv. Set 2	Mean Set 1	Mean Set 2
	telecommunication & transport	-1.01	1954.00	0.31	-23.88	7.68	-8.05	0.05
	energy & transport	-1.59	7521.05	0.11	-6.16	0.65	-2.70	0.05
	electricity & transport	-3.56	2247.13	0.00	-0.16	-0.05	-0.05	0.05
	oil and gas & transport	-1.57	5326.02	0.12	-8.65	0.96	-3.79	0.05
	water & transport	-0.96	435.10	0.34	-0.87	0.30	-0.23	0.05
	multi & transport	7.56	1094.99	0.00	0.02	0.03	0.08	0.05
	energy & telecommunication	0.65	2139.10	0.52	-10.79	21.49	-2.70	-8.05
	electricity & telecommunication	0.99	1954.05	0.32	-7.78	23.77	-0.05	-8.05
	oil and gas & telecommunication	0.51	2326.49	0.61	-12.24	20.75	-3.79	-8.05
	water & telecommunication	0.97	1959.39	0.33	-7.97	23.60	-0.23	-8.05
	multi & telecommunication	1.01	1954.00	0.31	-7.65	23.91	0.08	-8.05
	electricity & energy	1.52	7525.29	0.13	-0.76	6.05	-0.05	-2.70
	oil and gas & energy	-0.36	10192.83	0.72	-6.98	4.80	-3.79	-2.70
	water & energy	1.40	7854.28	0.16	-0.99	5.92	-0.23	-2.70
	multi & energy	1.60	7521.01	0.11	-0.63	6.18	0.08	-2.70
	oil and gas & electricity	-1.52	5327.52	0.13	-8.55	1.07	-3.79	-0.05
	water & electricity	-0.60	443.40	0.55	-0.77	0.41	-0.23	-0.05
	multi & electricity	4.46	2199.98	0.00	0.07	0.19	0.08	-0.05
	water & oil and gas	1.44	5470.81	0.15	-1.28	8.40	-0.23	-3.79
	multi & oil and gas	1.58	5326.00	0.11	-0.94	8.68	0.08	-3.79
	water & multi	-1.04	435.01	0.30	-0.90	0.28	-0.23	0.08

Source: Own Calculation

Table 15: Means of Tobin's Q of Different Sectors

Variable Tobin's Q	Data Sets 1& 2	T	DF	P-Value	95% Conf. Intv. Set 1	95% Conf. Intv. Set 2	Mean Set 1	Mean Set 2
	telecommunication & transport	2.90	1981.82	0.00	1.07	5.54	4.52	1.22
	energy & transport	2.16	7642.15	0.03	1.04	21.35	12.41	1.22
	electricity & transport	1.75	2227.07	0.08	-0.87	15.10	8.33	1.22
	oil and gas & transport	1.81	5414.06	0.07	-1.08	26.83	14.09	1.22
	water & transport	1.80	715.43	0.07	-0.01	0.13	1.28	1.22
	multi & transport	-3.61	1410.39	0.00	-0.10	-0.03	1.15	1.22
	energy & telecommunication	1.49	8324.12	0.14	-2.51	18.30	12.41	4.52
	electricity & telecommunication	0.90	2571.83	0.37	-4.48	12.10	8.33	4.52
	oil and gas & telecommunication	1.33	5684.84	0.18	-4.56	23.71	14.09	4.52
	water & telecommunication	-2.84	1983.62	0.00	-5.48	-1.01	1.28	4.52
	multi & telecommunication	-2.96	1981.23	0.00	-5.60	-1.13	1.15	4.52
	electricity & energy	-0.62	8660.75	0.54	-17.00	8.84	8.33	12.41
	oil and gas & energy	0.19	10568.27	0.85	-15.58	18.94	14.09	12.41
	water & energy	-2.15	7642.49	0.03	-21.29	-0.98	1.28	12.41
	multi & energy	-2.17	7642.04	0.03	-21.42	-1.11	1.15	12.41
	oil and gas & electricity	0.70	7566.97	0.48	-10.32	21.84	14.09	8.33
	water & electricity	-1.73	2227.23	0.08	-15.04	0.93	1.28	8.33
	multi & electricity	-1.76	2227.02	0.08	-15.17	0.80	1.15	8.33
	water & oil and gas	-1.80	5414.18	0.07	-26.77	1.14	1.28	14.09
	multi & oil and gas	-1.82	5414.02	0.07	-26.90	1.01	1.15	14.09
	water & multi	4.16	512.47	0.00	0.07	0.19	1.28	1.15

Source: Own Calculation

This result is equally supported by the tests based on the reduced subsets, which are displayed in the appendix in table 48, the results of the means in table 49.

Thus, the means of the sectors differ significantly. While the means of return on assets only differ for three pairs of sectors, for Tobin's Q eight pairs show significant differences.

5.5 Vertical Integration, Ownership and Services

The next subsets differentiate between firms owning nodes and/or edges (both), and firms owing nodes or edges and additionally offering services (services), and firms owning node and edges and additionally offering services (vertically integrated). The subsets are displayed in the figure 16.

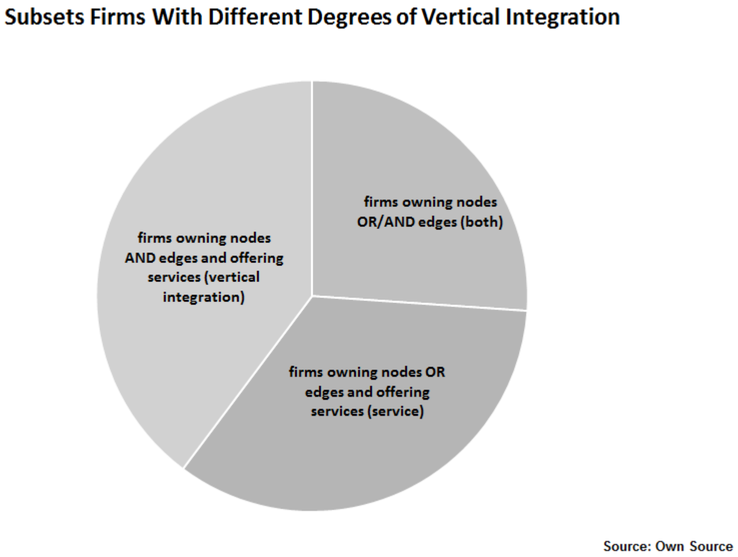


FIGURE 17: Creation of Subsets for Different Degrees of Vertical Integration

Again different models and tests are conducted as described in chapter 5.3.1. The fixed firms effects model with the following configuration is implemented.

$\mathrm{ROA}_{i,t} =$
$ln.TotAss_{i,t} + ln.SalesGrwoth_{i,t} + ln.DebtGrowth_{i,t} + ln.CapexGrowth_{i,t}$
$+DiviPayout_{i,t}+EarnDum_{i,t}+DivDum_{i,t}+PopGrowth_{c,t}+ln.GDPPCap_{c,t}+OECD-$
$Aggr_{c,s,t} + HHI_{i,c,s,t}$

and

Tobin's $Q_{i,t} =$
$ln.TotAss_{i,t} + ln.SalesGrwoth_{i,t} + ln.DebtGrowth_{i,t} + ln.CapexGrowth_{i,t} + BookToPrice_{i,t} + DiviPayout_{i,t} + EarnDum_{i,t} + DivDum_{i,t} + ln.PopGrowth_{c,t} + ln.GDPPCap_{c,t} + OECD - Aggr_{c,s,t} + HHI_{i,c,s,t}$

with i= firm, t= time, c=country and s=sector.

Serial correlation and heteroskedasticity do not lead to biased or inconsistent estimators, but lead to inefficient estimators (see e.g. Pindyck, Rubinstein (1998), p. 159), so that I estimate the robust covariance matrix estimation following Arellano (1987) with the years indicated. In several subsets the model with individual time effects proofs better than the model without. This cases are marked in the regressions and the individual time effects are again listed in the appendix.

5.5.1 Return on Assets

The results are displayed in table 16. The adjusted R^2 is low again, especially for the subsets of firms only owning nodes and/or edges (both) and firms owning nodes or edges and offering services (service). For vertically integrated firms the adjusted R^2 is high in comparison to all other conducted regressions on ROA with 0.148, including all regressions on the full set and the sectors.

While the correlations of the regressions of the subsets of firms offering services and being vertically integrated do only differ in detail from the regressions of the full set, the correlations of the regression of firms only owning nodes and/or edges (both) do differ. The logarithm of total assets exhibits an insignificant negative correlation instead of a negative one, equally does the logarithm of capital expenditures.

The dummy for dividends paid in the past five years shows a insignificant negative correlation. The population growth shows a positive but insignificant correlation.

In contrast firms additionally owning services (service) and vertically integrated firms both exhibit significant positive correlations.

The correlations of the indicator for regulation are significant negative for firms additionally offering services (service) and vertically integrated ones but is significant positive for firms only owning nodes and/or edges (both). Thus an important finding is, that firms who do not offer services do show higher return on assets when they face a strict regulation.

The correlations of the Herinfahl-Index (HHI) are significant negative for vertically integrated firms and for firms owning nodes and/or edges (both). Firms offering services have a positive but insignificant correlation. This supports the hypothesis, that the higher the market power is in contrast to the market, the higher are the returns on assets at least for the subsets "both" and "vertical integration".

The tests are displayed in the appendix in table 53, the variance inflation factors in table 58 and the individual time effects in table 55.

Table 16: Subsets of Different Degrees of Vertical Integration Regressed in Fixed Effects Models on the Dependent Variable ROA:
The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For the subset "vertical integration" individual time effects are identified and displayed in the appendix in table 55.

	Dependent variable:		
	ROA		
	(Both)	(Service)	(Vertical Integration^{+})
ln.TotAss	0.004	−0.0003	-0.011^{***}
	(0.005)	(0.006)	(0.003)
ln.SalesGrowth	0.005^{*}	−0.003	0.003^{***}
	(0.003)	(0.002)	(0.001)
ln.DebtGrowth	-0.003^{*}	−0.002	−0.001
	(0.002)	(0.002)	(0.001)
ln.CapexGrowth	0.0005	−0.0002	-0.002^{**}
	(0.002)	(0.001)	(0.001)
DiviPayou	-0.001^{***}	−0.0002	-0.0003^{***}
	(0.0002)	(0.0002)	(0.0001)
EarnDum	0.019^{*}	0.007	0.006
	(0.011)	(0.006)	(0.005)
DivDum	−0.009	0.010^{*}	0.006^{*}
	(0.010)	(0.006)	(0.003)
PopGrowth	0.003	0.018^{**}	0.020^{***}
	(0.008)	(0.008)	(0.007)
ln.GDPPCap	0.046	-0.097^{***}	0.034
	(0.066)	(0.034)	(0.027)
OECD-Aggr	0.020^{***}	-0.014^{**}	-0.015^{***}
	(0.005)	(0.006)	(0.003)
HHI	-0.043^{**}	0.009	-0.027^{***}
	(0.021)	(0.031)	(0.009)
Observations	532	754	1,190
R^2	0.056	0.037	0.195
Adjusted R^2	0.034	0.026	0.148
F Statistic	1.725^{*}	1.852^{**}	5.935^{***}
	(df = 11; 322)	(df = 11; 537)	(df = 37; 905)

Note: *p<0.1; **p<0.05; ***p<0.01
$^{+}$Individual time effects prevalent and displayed in the appendix.

Source: Own Calculation

5.5.2 Tobin's Q

The regressions on Tobin's Q using the different subsets based on ownership, services and vertical integration lead to results in the firm specific variables comparable to the full set (solely the correlation of the dummy for earnings of the past five years differs). In contrast the country and sector specific variables show different correlations for each set. The correlation of the logarithm of population growth is positive and significant for the subset of firms owning nodes and/or edges. It is insignificant positive for vertically integrated firms and is insignificant negative for firms offering services.

The correlation of the logarithm of GDP per capita (GDPPCap) shows a significant negative correlation for vertically integrated firms. Firms owning nodes and/or edges (both) and firms offering services exhibit insignificant positive correlations. The correlation for the regulatory indicator is significant and positive for vertically integrated firms, is insignificant but positive for firms owning nodes and/or edges (both), but is insignificant and negative for firms additionally offering services, but which are fully integrated.

The correlation of the Herinfahl-Index (HHI), measuring market power, shows an insignificant negative correlation for the subset of firms owning nodes and/or edges (both), a significant negative one for firms offering services and is insignificant positive for completely vertically integrated firms.

Individual time effects are only prevalent for vertically integrated firms. The time effects are mostly positive and insignificant, some are positive and significant.

The tests are displayed in the appendix in table 54, the variance inflation factors in table 58 and the individual time effects in table 55.

TABLE 17: Subsets of Different Degrees of Vertical Integration Regressed in Fixed Effects Models on the Dependent Variable Tobin's Q:
The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For the subset "vertical integration" individual time effects are identified and displayed in the appendix in table 55.

	Dependent variable:		
	Tobin's Q		
	(Both)	(Service)	(Vertical Integration^{+})
ln.TotAss	-0.057^{**}	-0.152^{**}	-0.068^{***}
	(0.028)	(0.071)	(0.019)
ln.SalesGrowth	0.074^{***}	0.009	0.022^{***}
	(0.021)	(0.020)	(0.006)
ln.DebtGrowth	−0.012	−0.004	-0.019^{***}
	(0.015)	(0.013)	(0.007)
ln.CapexGrowth	0.016	0.0003	−0.006
	(0.010)	(0.015)	(0.006)
ln.BookToPrice	-0.630^{***}	-0.704^{***}	-0.673^{***}
	(0.121)	(0.097)	(0.070)
lag(DiviPayou)	-0.002^{**}	-0.001^{*}	−0.001
	(0.001)	(0.001)	(0.001)
EarnDum	0.192^{**}	0.023	−0.034
	(0.089)	(0.055)	(0.039)
DivDum	−0.078	−0.010	−0.002
	(0.077)	(0.022)	(0.027)
ln.PopGrowth	0.049^{*}	−0.016	0.006
	(0.026)	(0.019)	(0.021)
ln.GDPPCap	0.522	0.034	-0.576^{*}
	(0.403)	(0.240)	(0.348)
OECD-Aggr	0.050	-0.071^{**}	0.037^{*}
	(0.065)	(0.034)	(0.021)
HHI	−0.474	-0.596^{**}	0.152
	(0.345)	(0.278)	(0.144)
Observations	444	626	996
R^2	0.391	0.351	0.581
Adjusted R^2	0.231	0.242	0.438
F Statistic	14.015^{***}	19.411^{***}	27.390^{***}
	(df = 12; 262)	(df = 12; 431)	(df = 38; 750)

Note: *p<0.1; **p<0.05; ***p<0.01
$^{+}$Individual time effects prevalent and displayed in the appendix.
Source: Own Calculation

5.5.3 Robustness Tests

For each of the subsets a reduced subset is created based on total assets. Each subset and firms are excluded having total assets
$\in [> mean(totalassets) + 2 * st.dev.(totalassets)]$.

The results of regressions, tests and the co-variance matrix estimator are displayed in the appendix in chapter A.0.4.3 in table 44 for ROA and in table 45 for Tobin's Q. For ROA the covariance matrix estimators are displayed in table 56, the tests in table 53, the variance inflation factors in table 58 and the individual time effects in table 55. For Tobin's Q the covariance matrix estimators are displayed in table 57, the tests in table 54, the variance inflation factors in table 58 and the individual time effects in table 55.

The number of observations regressed on ROA decreases by 20 and 71. The adjusted R^2s do not improve. The correlations do not change significantly. For the subset of vertically integrated firms neither significance nor insignificance or directions of correlations change, although 71 firms are excluded. For firms owning nodes and/or edges (both) the population growth changes from insignificant positive to insignificant negative.

For firms owning nodes or edges and offering services (service) the correlation of the logarithm of capital expenditures turns from insignificant negative to positive. This is also true for the correlation of the logarithm of capital expenditure growth. Additionally in this subset the correlation of the indicator for regulation (OECD-Aggr) turns from significant negative on the 5% level to insignificant. Thus a less strict regulation seems to increase the ROA for firms with comparably high total assets offering services.

For Tobin's Q the the robustness tests likewise does not lead to strongly varying results. The number of observations are reduced by 11 to 61 observations. The adjusted R^2 decreases for firms offering services, decreases slightly for firms only owning nodes and/or edges and increases for vertically integrated firms. Nevertheless the testing procedure implies a random effects model for the subset of vertically integrated firms with individual time effects instead of the in this thesis usually applied fixed effects model. This model is implemented. In comparison to the not reduced set of vertically integrated firms, only the correlation of the logarithm of GDP per capita (GDPPCap) turns insignificant as well as the one of the regulatory indicator (OECD-Aggr) does.

For the subsets of firms owning nodes and/or edges (both) and additionally offering services (service) the fixed effects model is implemented. For the subsets of firms owning nodes and/or edges (both) the logarithm of growth of capital expenditures turns significant, whereas the lagged dividends payouts turn insignificant.

For the subset of firms offering services the logarithm of GDP per capita (GDPPCap) turns from positive insignificant to negative insignificant.

5.5.4 F-Test for Different Means of Subsets of Different Level of Vertical Integration

The F-test examines whether the means of the performance variables (ROA and Tobin's Q) of the subsets differ significantly.

When the variances of the performance variables of the subsets differ, the Welch-Test has to be applied. Therefore in a first step the variables of the subsets are tested for differences in the variances. The tests are presented in the appendix in table 59. According to the test all of the subsets exhibit different variances so that the Welch-Test is applied to each combinations of variables of the subsets and presented in table 18.

According to the Welch-Test the ROA does not differ significantly between the different pairings of the subsets.

In contrast the Welch-Test indicates for the means of Tobin's Q that the subset of firms owning nodes or edges and additionally offering services differ significantly from the subset of vertically integrated firms. The first shows a higher mean than the second.

The reduced subsets based on total assets, which are applied in the robustness tests of the regressions, are also applied to the test of variances and the Welch-Test. The results do not differ: the means do not differ significantly for ROA. But the mean of Tobin's Q for the reduced subset of firms owning nodes or edges and additionally offering services (service) differs to the mean of the subset of vertically integrated firms. The test of differing variances can be found in table 60, the Welch-Tests for differing means in table 61.

Table 18: Means of Different Level of Vertical Integration

Variable	Data Sets 1& 2	T	DF	P-Value P-Value	95% Conf. Intv. Set 1	95% Conf. Intv. Set 2	Mean Set 1	Mean Set 2
ROA	both & vert. integr.	-1.74	3642.17	0.08	-20.76	1.24	-9.72	0.04
ROA	service & vert. integr.	-1.59	3738.45	0.11	-0.58	0.06	-0.22	0.04
ROA	service & both	1.69	3648.05	0.09	-1.50	20.50	-0.22	-9.72
TQ	both & vert. integr.	1.52	3732.14	0.13	-4.46	35.49	16.94	1.43
TQ	service & vert. integr.	2.79	3597.47	0.01	2.61	14.99	10.23	1.43
TQ	service & both	-0.63	4438.40	0.53	-27.62	14.19	0.00	10.23

Source: Own Calculation

5.6 Analyses of Directed versus Undirected Networks

The last analyses focus on directed networks with indirect network effects and undirected networks with direct network effects. In this sample it should be tested whether the performance of undirected networks has a higher, significant positive correlations with population growth which approximates market size. Therefore two subsets are created, one including all firms which are active in directed networks and one with the firms active in undirected networks. The subset of undirected networks contains less firms, based on the fact that all firms of the transport sector and most of the telecommunication sector are included. Multis, firms active in several sectors, are not included in any subset.

Again different models and tests are conducted as described in the appendix in table A.0.5.

Comparably to the last analyses the different models and tests are applied. The fixed effects model is implemented. Because again serial correlation and heteroskedasticity are prevalent and lead to inefficient estimators (see e.g. Pindyck, Rubinstein (1998), p. 159) I estimate the robust covariance matrix estimation following Arellano (1987). In several subsets the model with individual time effects proofs better than the model without. This cases are marked in the regressions and the individual time effects are again listed in the appendix in table 51.

$$\mathrm{ROA}_{i,t} =$$
$$ln.TotAss_{i,t} + ln.SalesGrwoth_{i,t} + ln.DebtGrowth_{i,t} + ln.CapexGrowth_{i,t}$$

$+DiviPayout_{i,t}+EarnDum_{i,t}+DivDum_{i,t}+PopGrowth_{c,t}+ln.GDPPCap_{c,t}+OECD-Aggr_{c,s,t}+HHI_{i,c,s,t}$

and

Tobin's $Q_{i,t} =$
$ln.TotAss_{i,t}+ln.SalesGrwoth_{i,t}+ln.DebtGrowth_{i,t}+ln.CapexGrowth_{i,t}+BookToPrice_{i,t} + DiviPayout_{i,t} + EarnDum_{i,t} + DivDum_{i,t} + ln.PopGrowth_{c,t} + ln.GDPPCap_{c,t} + OECD - Aggr_{c,s,t} + HHI_{i,c,s,t}$

with i= firm, t= time, c=country and s=sector.

The two subsets, firms active in undirected and directed networks, are regressed towards ROA. The model fit is higher for the subset of firms active in directed networks, with the adjusted R^2 of 0.80 and 0.39 for the set of firms active in undirected networks. The number of observations of the firms active in directed networks is almost a third of the subset of firms active in undirected networks.

While in the full set the correlation of the logarithm of total assets shows an insignificant negative correlation with ROA, firms active in directed networks exhibit an insignificant positive correlation, and firms active in undirected networks a significant negative one. Comparably the correlations of the logarithm of sales growth differ, it is significant positive for directed networks and insignificant negative for firms in undirected networks. In the full set an insignificant negative correlation is prevalent. The correlation of the logarithm of growth of capital expenditure is insignificant negative for firms in directed networks and is positive for firms in undirected ones. Dividend payouts show a significant negative correlation for firms in directed networks and a insignificant positive one for undirected networks. The dummies for dividend payouts and earnings of the past five years show positive correlations and are significant for earnings of firms in undirected networks.

The correlations of population growth are for both significant and positive. The correlation of the logarithm of GDP per capita (GDPPCap) is insignificant and negative for the set of firms in directed networks but is significant and positive for the set of firms active in undirected networks.

The indicator for regulation has a significant negative correlation on the 5% level for firms active in directed networks and an insignificant negative one for firms in undirected networks. Thus while firms in directed networks have a higher ROA when regulation is less strict, this relationship is not supported by the regression for firms active in undirected networks.

The correlations of the Herinfahl-Index (HHI) are insignificant and negative for both subsets.

Time effects are only prevalent for firms active in directed networks. As in the other sets these are negative and significant, indicating that the applied variables do not map the development of the market power and competition sufficiently.

The correlations of the regressions on Tobin's Q of the two subsets, comparably to the regression of the subsets of ownership, services and vertical integration, do not differ from the full set in the firm specific variables. But the insignificant correlation of the logarithm of growth of capital expenditure is positive for firms active in directed networks, and the ones of the dummies for dividends paid in the past five years and earnings gained in the past five years differ, but are insignificant.

In contrast the country and sector specific correlations of variables differ for firms active in directed and undirected networks. While the correlation of the logarithm of population growth is significant positive for both subsets, the logarithm of GDP per capita (GDPPCap) is insignificant negative for directed networks and positive for firms active in undirected networks. The correlation of the indicator for regulation is insignificant negative for firms active in undirected networks but positive for firms active in directed networks.

The Herinfahl-Index (HHI) exhibits a significant negative correlation for firms active in directed networks and an insignificant negative one for firms active in undirected networks.

The tests for ROA and Tobin's Q are displayed in the appendix in table 61, the variance inflation factors in table 64 and the individual time effects in table 62.

TABLE 19: Fixed Effects Models for bot Performance Variables for Different Types of Networks:
Fixed Effects Model, using Arellano robust covariance matrix estimation. The total set of all firms is split into two sets, one only including firms active in directed networks (water, oil & gas, electricity, broadcasting) , one including firms active in undirected networks (most telecommunication and transport).

	Dependent variable:			
	ROA		TQ	
	(Directed+)	(Undirected)	(Directed+)	(Undirected+)
ln.TotAss	0.002	−0.018**	−0.080***	−0.277**
	(0.002)	(0.007)	(0.025)	(0.117)
ln.SalesGrowth	0.004***	−0.004	0.034***	0.038**
	(0.001)	(0.003)	(0.013)	(0.016)
ln.DebtGrowth	−0.002*	−0.003	−0.009	−0.030*
	(0.001)	(0.002)	(0.008)	(0.016)
ln.CapexGrowth	−0.001	0.001	0.011	−0.009
	(0.001)	(0.002)	(0.007)	(0.021)
DiviPayou	−0.0004***	0.0001		
	(0.00005)	(0.0002)		
ln.BookToPrice			−0.565***	−0.802***
			(0.068)	(0.112)
lag(DiviPayou)			−0.002***	−0.0003
			(0.0005)	(0.001)
EarnDum	0.003	0.020***	0.083*	−0.059
	(0.005)	(0.007)	(0.047)	(0.061)
DivDum	0.002	0.004	−0.020	0.071
	(0.005)	(0.007)	(0.030)	(0.060)
PopGrowth	0.018***	0.026**		
	(0.005)	(0.013)		
ln.PopGrowth			0.042***	0.077***
			(0.015)	(0.027)
ln.GDPPCap	−0.012	0.070**	−0.243	0.005
	(0.032)	(0.028)	(0.338)	(1.350)
OECD-Aggr	−0.008**	0.002	0.011	−0.013
	(0.004)	(0.003)	(0.025)	(0.048)
HHI	−0.007	−0.027	−0.293**	−0.433
	(0.012)	(0.025)	(0.115)	(0.352)
Observations	1,573	540	1,305	441
R^2	0.114	0.057	0.438	0.499
Adjusted R^2	0.080	0.039	0.303	0.294
F Statistic	3.857***	2.031**	18.502***	7.003***
	(df = 37; 1107)	(df = 11; 367)	(df = 38; 903)	(df = 37; 260)

Note: *p<0.1; **p<0.05; ***p<0.01
+Individual time effects prevalent and displayed in the appendix.
Source: Own Calculation

5.6.1 Robustness Tests

Two reduced subsets are created based on total assets. Firms having total assets
$\in [> mean(totalassets) + 2 * st.dev.(totalassets)]$
are excluded.

The results of regressions, tests and the covariance matrix estimator are displayed in the appendix in chapter A.05. The covariance matrix estimators for ROA and Tobin's Q are displayed are displayed in table 64.

The number of observations for the regression on ROA decreases by 26 and 75.

The adjusted R^2s decrease for both subsets for the regressions on ROA. For directed networks the significant correlation of the regulatory indicator turns insignificant. For undirected networks the correlation of the logarithm of total assets turns insignificant while the one of logarithm of sales growth turns significant. The correlations of the other explanatory variables do not change in direction or significance.

The number of observations for the regression on Tobin's Q decrease by 73 for firms active in undirected networks and 24 for firms in directed networks. The adjusted R^2s decrease for both subsets. Nevertheless the correlation of the variables only change slightly. For the subset of firms active in undirected networks the correlation of the logarithm of growth of capital expenditure turns significant. For firms active in directed networks the logarithm of population growth turns insignificant.

Time effects are only prevalent for firms active in undirected networks. The time effects are mostly insignificant and only two effects are positive and significant.

The covariance matrix estimators for ROA and Tobin's Q are displayed in table 64, the tests in the table 61, the variance inflation factors in table 64 and the individual time effects in table 65.

5.6.2 F-Test for Differing Means

The F-Test examines whether the mean of the performance variables (ROA and Tobin's Q) of the subsets differ significantly.

When the variances of the performance variables of the subsamples differ, the Welch-Test has to be applied. Therefore in a first step the variables of the subsets are tested for differences in the variances. The tests are presented in the appendix in table 65.

According to the tests the variables of the subsets have different variances, so that the Welch-Test is applied to each combination of variables of the subsets and presented in table 20. The tests highlight that the means of the different subsets and performance variables do not differ for ROA

In contrast the mean of Tobin's Q of the set of directed networks is significantly higher in contrast to the mean of the set of undirected networks.

The reduced subsets based on total assets, which are applied in the robustness tests of the regressions, are also applied to the test of variances and the Welch-Test. The results do not differ from the main setting, the means do not differ for ROA but differ for Tobin's Q. The tests for differing variances are in table 65, the Welch-Test for differing means in the appendix in table 66.

TABLE 20: Tests for Differing Means for Different Types of Networks

Variable	Data Sets 1& 2	T	DF	P-Value	95% Conf. Intv. Set 1	95% Conf. Intv. Set 2	Mean Set 1	Mean Set 2
ROA	direct. & undir.	0.56	2984.96	0.58	-8.73	15.73	-2.51	-6.00
TQ	direct. & undir.	2.10	8305.25	0.04	0.66	19.48	12.10	2.03

Source: Own Calculation

5.7 Summary of Findings

The description of the development of infrastructure assets and the demand for services highlighted the increasing need for available and reliable infrastructure services. This request is met by an increase of listed firms active in infrastructure for each sector and each country for the period 1980-2007. Equally for all firms active in the market median and mean of variables such as sales, earnings, assets or market capitalization increased. But the descriptive statistics also revealed an increase in the disparity in the values of the firms, emphasized by increased maxima and decreased minima but also by an increased standard deviation. These findings are comparably true for the two performance variables, return on assets and Tobin's Q.

To test the hypotheses several empirical analyses of different configurations and subsets on the two dependent variables are conducted.

The first important finding of the empirical analyses is that the model fit for ROA is low compared to the fit for Tobin's Q. The correlations of some variables in the models react sensitively to changes in configurations and to different subsets. This is especially true for the country- and sector-specific variables in the regressions on Tobin's Q. While the sets and subsets all are heteroskedastic, serial correlation is not prevalent within each of the configurations and subsets. Nevertheless, the arellano covariance matrix could be applied in both cases.

Hypothesis 1 -Monopolistic Structures:
The number of firms owning and operating infrastructure increased in the period 1980 until 2007. To map this development the Herinfahl-Index (HHI) and the ToNumOfFirms are calculated. Values equal one indicate complete market power, the smaller the value of the indicators is, the smaller is the market power of the firm. None of these indicators show the expected significant positive correlation in the configuration of the full set, the sectors, properties (owning nodes and/or edges, additionally offering services and fully vertically integrated firms) or types of networks (directed and undirected networks) on ROA. They show negative mostly significant negative correlations. The correlations of Tobin's Q are equally negative but often not significant.

Important to mention are individual time effects. In many sets and subsets with the dependent variable ROA the individual time effects are assessed to be of significance. The time effects exhibit mostly significant negative correlations on ROA. Therefore one can assume that the increase of firms and competition and the decrease of regulation is not satisfyingly incorporated in the model. Another reason could be that firms are active on international markets and that therefore international competition is not sufficiently mapped by the indicators.

The hypothesis is rejected.

Hypothesis 2 -Regulation:
The liberalization of markets is assumed to increase competition and impede monopolistic earnings. The regulatory indicator ranges between 0 and 6, with 0 indicating no regulation and 6 indicating a strict regulatory regime. Thus regulation should

show a negative correlation for the performance indicators. Nevertheless the findings here are inconsistent.

First, regressions on ROA show mostly negative, often significant correlations of the regulatory index. Thus firms have a higher ROA in countries with less regulation. This could be based on the assumption that increased competition also increases the incentive to reduce costs and improve products. Another reason could be that in less regulated sectors and countries no price-, incentive-, profit- or quantity-regulations exist which reduce profits.

Second, this is not true for firms only owning edges and/or nodes (both), they show a significant positive correlation of the regulatory indicator on ROA. Firms only owning infrastructure thus profit from stricter regulation maybe related to access-prices. For Tobin's Q this correlation is equally true, but it is insignificant for firms owning nodes and/or edges, while it is significant and positive for vertically integrated firms. The market assesses a stricter regulatory regime as beneficial in the future for vertically integrated firms.

Third, for Tobin's Q the correlation of the regulatory indicator is mostly positive and significant in the full set. Here investors prefer to invest in regulated markets. But these correlations are not supported by significant values in the sector specific analyses.

Thus the hypothesis can not be rejected.

Hypothesis 3 -Differing Sectors:
A pivotal question of this thesis is whether infrastructure can be treated uniformly. The theoretical part of the thesis develops an argumentation for assessing sectors and subsectors differently, based on their properties and network types. The regressions on the dependent variables show that the models exhibit different fits to the sectors. The sectors show different correlations for the variables. Thus it might be justified to assume that sectors differ in their performance. Accordingly the regressions on Tobin's Q reveal that investors assess the variables differently for firms active in each sector.

The Welch-Tests for varying means support the hypothesis that different sectors show significant unequal means of the variables ROA and Tobin's Q.

Thus the hypothesis can not be rejected.

Hypothesis 4 -Vertical Integration:
Vertically integrated firms should perform better than firms only owning nodes and/or edges. But the Welch-Tests show no differences in the means of ROA. But the tests show significant differences for the means of Tobin's Q of firms additionally offering services and firms being completely vertically integrated. The latter exhibit smaller means than the firms offering additionally services.

Complementary the regressions highlight differences in the country and sector specific variables. Vertically integrated firms and such offering services exhibit negative correlations with the indicator for regulation for ROA. Thus they might be able to integrate economies of scale and scope when regulation is low. In contrast firms owning nodes and/or edges perform better under stricter regulatory regimes, resulting in a higher ROA.

Thus the hypothesis can not be rejected.

Hypothesis 5 -Direct and Indirect Network Effects:
Firms active in undirected networks with direct and indirect network effects should profit more from population growth as an increase in demand of the market and an increase in consumption means, proxied by the in GDP per capita. The empirical analyses show that the correlation of the logarithm of population growth is almost always significant positive on the dependent variables ROA and Tobin's Q.

The logarithm of GDP per capita in contrast exhibits contradictory results for the different dependent variables, subsets and sectors.

The Welch-Tests do not exhibit significant different means of ROA for the two subsets. But Tobin's Q shows a significant higher mean for directed networks.

Additionally the correlations of population growth on both dependent variables are significant and positive and have higher values for undirected network effects. The correlation of the GDP per capita is insignificant negative for directed networks, but is significant positive on the ROA in undirected networks and is insignificant but positive on Tobin's Q in undirected networks. These correlations and significances are equally true for the reduced subsets of the robustness tests.

Thus the hypothesis can not be rejected.

Chapter 6

Conclusion: Findings and Critical Discussion

6.1 Summary of Findings

Infrastructure has not been defined in a proper way so far. Therefore I developed a definition of economic infrastructure which is based on the assumption of physical networks and thus is based on network theory and theory of competition. This definition excludes so-called "social infrastructure", such as education, health or culture. While economic infrastructure always consists of edges and nodes, social infrastructure consists of unconnected nodes[1].

This definition has several, important advantages. It creates the opportunity to differentiate between directed and undirected networks. Undirected networks[2] have the significant property that every additional node in the network increases the benefit for any existing member in the network (e.g. telecommunication and transport). Therefore, the so-called positive direct network effect creates a different demand

[1] Of course, hospitals for example are connected by roads. But the roads are not specifically built for connecting hospitals. Hospitals use the transport services of roads as anybody else. Comparably there are data systems in the health-care-system, using the telecommunication systems to exchange data, but here again, this network is not build to provide health services, but is an existing network, to offer data transfer services to consumers.

[2] There are no start or end nodes and there is no specific direction which has to be met; this is in contrast to water networks, where the water can only flow in one direction.

structure than the one prevalent in markets without direct network effects. But additionally directed networks also show indirect positive network effects. Based on high scale effects, every additional participant in the network decreases the costs for the other participants disproportionately. These indirect effects are also prevalent in undirected networks. Due to high costs and scale effects, a network needs more than one consumer to get built. Undirected networks only function when several consumers exist, e.g. in telecommunication. Buying and owning a telephone does not have any benefits when there is no one else to talk (see e.g. Economides (1994)).

This leads to another important feature of networks - standards and compatibility. As it is only useful to own a telephone when someone else owns a telephone, it is also important that the technology is compatible and both consumers can access the same network. It is necessary that trains face the same gauge-size when crossing borders and that electrical devices use the same plugs and types of energy, otherwise a huge amount of adapters and transformers for each device would be necessary[3]. The fact that any network, once built, can hardly be used for other means or in other areas, leads to monopolistic or at least oligopolistic structures in many parts of infrastructure (see e.g. Sharpiro, Katz (1985)).

Monopolistic and oligopolistic structures are intensified by vertical integration in these industries and the network effects of infrastructure. Vertical integration offers an integrated firm the possibility to distort competition in the different levels of infrastructure. A telecommunication firm owning the land-line infrastructure prefers to offer this structure for free to an integrated service firm and to impede access to the structure for other competing service companies. Thus vertical integration constrains competition. But as monopolistic structures usually result in high prices for consumers, vertical integration might also lead to lower prices, as different theoretical papers for other network industries show; this is based on the fact that, when two monopolistic firms in a vertical relation merge, they internalize one monopolistic price. This is called double marginalization (see e.g. Tirole (1988) and Harrington, Vernon (2005)).

[3]An interesting contemporary example is the new EU legislative, which expects all smart-phone producers to produce the identical compatible adapter and serial interface for all smart-phones to avoid the waste of charging adapters.

Even so the economic properties were not defined in detail until the work of Baumol, Panzar and Willig in 1978, most countries defined infrastructure as “natural monopolies”. A monopoly is usually assumed to sell products at high prices and to offer smaller quantities and lower quality so that infrastructure and services were mostly provided by governments. This is true for most countries and sectors even though several examples for private provision of telecommunication and rail transport can be found in the United States (US) and the United Kingdom (UK).

These early examples of the private provision of infrastructure showed several shortcomings based on the properties of networks and scale effects. In the US, even though there were several competing telecommunication companies, network structures did not allow access to the network of the competitor and thus imposed the necessity for businesses to have several contracts and physical telephones to be available for all customers. With regard to transport, privately owned infrastructure was not built in less prosperous areas so that economic development in these areas fell behind even more (see for both arguments Vogelsang (2003), p. 831 pp).

The trend that most infrastructures were provided publicly changed in the late 80s. Privatization has various advantages compared to public provision. Most of these advantages are based on the ownership structure and are discussed in the field of principal-agent theory. The main argument in the field of private and public provision is that state-owned companies do not need to be profitable. When a public firm makes losses, the government will always have an incentive to balance these losses, support the firm and maintain the provision of the service instead of forcing the firm into insolvency. The management of the firm is aware of this fact and does not have the incentive to decrease costs, lay off employees, improve processes or use other straining means. Compared to that, the owner of a private firm is incentivized to improve the processes, lay off employees when necessary and cut costs to increase his own surplus. Based on principal-agent theory, most of these incentives can be transferred to a manager by contractual means (see for all arguments e.g. Tirole (1988), p. 35pp).

Another important factor in public provision is the fact that politicians often abuse the public firm to favor political groups or even friends. Infrastructure projects represent the dream of politicians to create something immense and remarkable. This phenomenon leads to excessive and wasteful investments.

Private provision of infrastructure has advantages per se in the structure of the management of the firm and the goals of the firm but has incentives to exploit its position by reducing quality and quantity and increasing prices, and therefore threatening economic development.

This conflict could be solved by the regulation of the private companies. Regulation could guarantee that everyone has access to the infrastructure. It is necessary to impose standards so that services and products can be switched; a minimum level of quality, for example in terms of safety, ensures the reliability of infrastructure. To prevent monopolistic structures in services, third parties must have the opportunity to access the network by paying fair prices. Prices for network access and prices for goods and services have to be kept below the monopolistic prices. Therefore a set of tools for regulating a market has been established: public ownership, vertical integration, price regulation, quantity regulation and the regulating agency.

This theoretical approach leads to the five hypotheses to be tested in the empirical part of the paper. The hypotheses summarized are: direct and indirect network effects lead to different development of the performance in correlation with changes of the market; ownership and operation of nodes or edges can be associated with different competitive environments and thus influence performance; vertical integration enhances the performance of firms compared to firms only owning nodes or edges by exploiting their market power; each infrastructure sector differs substantially from the other sectors in terms of correlations and performance; regulation increases competition and thus reduces performance; but in combination with direct network effects this could also lead to an increase of the performance by increasing the relevant network and thus the customers.

To be able to examine infrastructure precisely I discussed all relevant sectors individually. For each infrastructure sector it was showed which nodes and edges have monopolistic structures and which nodes, especially the root and end nodes, have competitive properties. This detailed differentiation gives the possibility to analyze and list substitutes in the different sectors and different sector parts - a question which has hardly been addressed so far. Of course, transport by planes is not a perfect substitute for transport by ships, but in several cases one can substitute for the other. Similarly, when eMobility increases, wind and solar energy can replace petrol as single energy supplier in car transport.

Another significant finding is the ability to differentiate between real infrastructure (ports, roads, cables, pipelines etc.) and services which are offered on these networks. Services, like transport services, energy supply or submitted telecommunication data, can be offered on different networks. Planes, trains and trucks can serve new routes or transport different goods easily, even on different continents. Energy can be supplied via trucks or ships instead of pipelines, electricity can (at least in the short term) be stored and transported with any possible means.

This in-depth analysis of the different sectors forms the basis for the discussion of governmental provision of infrastructure, privatization and regulation. As the assessment of competitive structures and the in-depth analysis of the sectors develop, competition in infrastructure is possible: between different sectors, between root nodes or end nodes and especially between services. But vertical integration mitigates this competitive opportunities as a vertically integrated firm does not have the incentive to allow access to its infrastructure. Additionally the firm has the incentive to prevent network services of other companies by introducing different standards.

The empirical analyses are conducted using a panel set of listed firms owning and operating infrastructure. The set covers the period from 1980 until 2007. The firms are listed in 36 countries. While a set of 36 countries and 1.491 firms is used in the descriptive part, the set is reduced to 31 countries and 1.210 firms in the empirical part, resulting of missing data. The main set of firms is also used in Rothballer (2012), Kaserer and Rothballer (2012) and Rödel, Rothballer (2012). The analyses are supported by country specific data from the OECD and the OECD indicator for regulation.

In the empirical analyses robust covariance estimators for fixed effects models are applied to treat for heteroscedasticity and serial correlation. The model fit is better for regression on Tobin's Q than on return on assets (ROA). Tobin's Q maps the future expected performance based on the stock market's expectations related to its assets, while ROA displays the current performance of the firms. Different subsets with regard to sectors, properties (firms owning nodes and/or edges, firms owning nodes or edges but offering services and vertically integrated firms) and network types (firms active in directed or undirected networks) are created.

The first important finding of the empirical analyses is that the model fit for ROA is low compared to the one of Tobin's Q. The correlations of some variables in the models react sensitively to changes in configurations and to different subsets. This sensitivity can be especially observed for the country- and sector-specific variable (such as the regulatory index, proxies for market demand and purchasing power of market power) in the regressions on Tobin's Q. While the sets and subsets all are heteroskedastic, serial correlation is not prevalent within each of the configurations and subsets. Nevertheless, the arellano covariance matrix could be applied in both cases.

Tests on different means of the sectors show, that sectors exhibit significantly different means of ROA and Tobin's Q. Regressions on ROA and Tobin's Q reveal that the explanatory variables do influence them differently. So it seems that treating sectors differently is advantageous for investors and politicians.

The correlations of the indicator for regulation are negative and often significant for regressions on ROA, but are positive for the regressions on Tobin's Q. Investors seem to assess the long term performance of countries with stricter regulation higher than the value of assets in countries with less regulation, while the current performance is better for firms with less regulation, as firms are less confronted with price-, incentive-, profit- or quantity regulations.

Splitting the set of firms in three subsamples, the first only owning nodes and/or edges, the second owing nodes or edges and additionally offering services and the third sample only containing completely vertically integrated firms reveals two important findings. First, the set of firms, which only own nodes and/or edges do show positive correlations of the regulatory indicator to the dependent variables ROA and Tobin's Q. These correlations mark that stricter regulation increase the current and expected performance of these firms. One explanation could be that access prices or entry barriers of strict regulation protect the monopolistic situation of these firms.

In contrast the regulatory indicator shows negative correlations for the regressions of the subsamples of firms offering services and the ones being completely vertically integrated. Here less regulations improves the ROA. In the short term, less regulation might increase the market power of the firms, which might enable firms to exploit the opportunities of partly vertical and complete vertical integration.

Significant positive correlations are exhibited for population growth for both dependent variables in almost all regressions. Population growth proxies the increasing demand for infrastructure. This is necessary because data for demand of specific infrastructure services is available but still is fragmentary. Thus in countries with a growing population the performance of firms increase, while in countries with decreasing population, equally the performance of firms decrease.

Likewise GDP per capita is applied in the models to map the demand based on the purchasing power of the countries. Here most of the correlations are negative. Thus firms in countries with smaller purchasing power do perform better.

One of the hypotheses developed in the thesis states that firms active in undirected networks do profit more from an increase in demand, proxied by population growth and GDP per capita, then firms active in directed networks. This is based on direct network effects, prevalent only in undirected networks. The correlation of population growth on ROA and Tobin's Q is significant positive for undirected and directed networks. The significant positive correlation shows a higher value for undirected networks. This correlation is supported by the GDP per capita, showing positive correlations on ROA and Tobin's Q for firms active in undirected networks and negative ones for firms active in directed networks.

The market power, mapped by the Herinfahl-Index, shows significant negative correlations in regressions on ROA and insignificant negative ones on Tobin's Q in almost all regressions and sets. An increase in competition increases performance. This could be explained by the incentive competition creates to reduce costs and improve structures and products.

In many of the regressions individual time effects are identified. The time effects on ROA are mostly significant negative, the time effects on Tobin's Q are mostly insignificant positive. These time effects might indicate that the developments of firms active in infrastructure are not mapped sufficiently by the implemented models.

6.2 Critical Discussion and Further Research

The critical discussion tries to close the loop between theory and the empirical application. So it will start with a short discussion of the definition. While the OECD-Indicator for regulation and a suggestion for a more detailed one is discussed in the empirical part, in this chapter other shortcomings of the analyses are presented.

6.2.1 Critical Discussion of the Definition

The definition of economic infrastructure developed in this thesis can be understood as a combination of different existing discussions and theories. But it also has the ability to create a common basis for further discussions of infrastructure, infrastructure financing and market failure. This is especially important when new networks based on new technology emerge. One example is the development of eMobility and the need to develop an electricity network accessible for cars during work or when not owning an own garage, a situation especially common in urban areas.

The questions in this context are of economic and political nature: assuming that a government wants to reduce CO_2 emissions and thus wants less fossil energy to be used and transport fuel by petrol to be replaced by eMobility, who constructs, finances, owns and operates the infrastructure. Investments upfront might be too high to be made by one firm and too high for the individual eMobility-car owner. The combination of different fields of research and the theoretical foundation based on that definition creates a tool applicable for existing networks and creates the awareness that different parts of the networks have different properties which have to be considered in regulation and liberalization.

A second important point to mention is that social infrastructure is not considered. Social infrastructure, such as hospitals, schools, universities and others, is not included in my analyses. I would suggest a spatial competition model (See e.g. Tirole (1988)). The topic of social infrastructure seems even more complicated to find a definition for, since many of the ensuing questions are of political nature and concern the impact on society, so it might be preferable to discuss this in political or social sciences.

6.2.2 Critical Discussion of the Empirical Research

As stated, the indicator for regulation does not suffice the infrastructure definition made in this paper. But the empirical analyses have other shortcomings to be mentioned.

The firms and their assessment of infrastructure ownership and operations were conducted based on information gathered in January, February and March 2010 from Thomson and from the income statements of the companies. So for the assessment of firms' activities we used the information available in the year 2010 and thus used documents covering the year 2009. Changes in ownership and operation of infrastructure assets before or after this date were not included in the assessment of firms' activities. Thus including developments of firms and their acquisitions of new network parts or services and thus activities towards vertical integration might improve the empirical findings.

To assess infrastructure and its economic properties in more detail, it would also be beneficial to identify whether companies in electricity and oil & gas are active in root nodes or only in joints. The hypothesis, that the ownership of root- and end-notes which are assumed to be monopolistic in contrast to competitive joint nodes and edges could not have been conducted. This might be an important point in different sectors, as root nodes are highly competitive, while joint nodes have monopolistic characteristics.

An important topic, especially when considering the analyses of the sectors, is the infrastructure network itself. In the empirical part of this thesis, the network was approximated by population growth and GDP per capita. Especially the approximation of GDP per capita provided contradictory insights.

Applying real data on the infrastructure network into empirical analyses can give additional information for the assessment of direct and indirect network effects on firms' result. But until today infrastructure data is far from complete, the data on infrastructure was obtained from the CIA or from the OECD. As the chapter on the descriptive statistics on countries shows, the data covers often only some countries and some years, reliability of the assessment is also a problem. Additionally, vast amounts of missing data, when applied to an unbalanced panel data set, with equally missing data, decreases the number of observations and time lines and thus might turn out to create a fruitless empirical analysis.

The countries' politics and regulations as well as size, population and GDP are of importance for the firms' financial results. But within the data set we could not differentiate between profits generated from infrastructure in the country the firm is listed and profits made abroad and assumed that all profits were generated in the country the firm is listed.

Firm owners, politicians and regulators would benefit from an empirical analysis where firms active in infrastructure sectors are compared to firms active in other sectors. Although the analysis on the basis of the different sectors has shown that even within the scope of infrastructure industries differences exist, a comparison to, for example, real estate companies, could shed some more light on the influence of the infrastructural characteristics but could also lead to misconceptions due to different capital structures.

The last, and maybe most important fact to mention is the very new development of firms active in infrastructure industries. The number of firms listed on stock exchanges developed from 145 in 1980 to 1,491 in 2007. Some of the firms might be privatized firms, but many might have had to finance the construction of infrastructure. The steady cash flows of these investments might not outweigh the current ongoing investments and costs of debt. Thus, the analyses might show different results after some more years of active firms in the market. Referring to that a consolidation of firms active in specific infrastructure sectors might be expected in the next years.

Appendix A

Appendix

A.0.3 Correlation Matrix for the Variables of the Empirical Analyses

Table 21: Correlation Matrix for the Variables Applied in the Empirical Analyses

	ROA	TQ	ln.TotAss	ln.SalesGrowth	ln.DebtGrowth	ln.CapexGrowth	ln.BookToPrice1
ROA	1	-0.322	0.092	-0.093	-0.004	-0.027	0.228
TQ	-0.322	1	-0.096	0.052	0.010	0.030	-0.183
ln.TotAss	0.092	-0.096	1	-0.291	-0.238	-0.337	0.211
ln.SalesGrowth	-0.093	0.052	-0.291	1	0.411	0.410	-0.221
ln.DebtGrowth	-0.004	0.010	-0.238	0.411	1	0.429	-0.195
ln.CapexGrowth	-0.027	0.030	-0.337	0.410	0.429	1	-0.198
ln.BookToPrice	0.228	-0.183	0.211	-0.221	-0.195	-0.198	1
DiviPayou	0.016	-0.020	0.431	-0.390	-0.307	-0.337	0.241
PopGrwth	-0.006	0.007	-0.154	0.028	-0.028	0.034	-0.055
lnPOPGrwth	-0.006	0.008	-0.149	0.053	-0.007	0.040	-0.066
ln.GDPPCap	-0.011	0.020	-0.173	0.064	-0.006	0.063	-0.153
OECD-Aggr	0.009	-0.012	0.214	-0.124	-0.033	-0.111	0.157
HHI	0.008	-0.016	0.050	0.057	0.117	0.030	-0.032
NumOfForms	0.006	-0.011	0.173	-0.038	0.038	-0.041	0.023

	DiviPayou	PopGrowth	lnPOPGrwth	ln.GDPPCap	OECD-Aggr	HHI	NumOfFirms
ROA	0.016	-0.006	-0.006	-0.011	0.009	0.008	0.006
TQ	-0.020	0.007	0.008	0.020	-0.012	-0.016	-0.011
ln.TotAss	0.431	-0.154	-0.149	-0.173	0.214	0.050	0.173
ln.SalesGrowth	-0.390	0.028	0.053	0.064	-0.124	0.057	-0.038
ln.DebtGrowth	-0.307	-0.028	-0.007	-0.006	-0.033	0.117	0.038
ln.CapexGrowth	-0.337	0.034	0.040	0.063	-0.111	0.030	-0.041
ln.BookToPrice	0.241	-0.055	-0.066	-0.153	0.157	-0.032	0.023
DiviPayou	1	-0.039	-0.042	-0.163	0.235	-0.049	0.100
PopGrwth	-0.039	1	0.872	0.163	-0.332	-0.434	-0.330
lnPOPGrwth	-0.042	0.872	1	0.215	-0.377	-0.436	-0.372
ln.GDPPCap	-0.163	0.163	0.215	1	-0.750	-0.476	-0.550
OECD-Aggr	0.235	-0.332	-0.377	-0.750	1	0.396	0.566
HHI	-0.049	-0.434	-0.436	-0.476	0.396	1	0.750
NumOfForms	0.100	-0.330	-0.372	-0.550	0.566	0.750	1

Source: Own Calculation

A.0.4 Additional Empirical Data for the Full Set

A.0.4.1 Empirical Tests

Table 22: Tests for Fixed Effects Models on ROA and Different Configurations: For each configuration on the dependent variable ROA tests are executed to determine whether the panel data can be estimated versus a simple ordinary least square model or whether fixed effects and random effects are the better fit. Additionally the test results for heteroskedasticity and serial correlation are displayed. For the decreased subsets to conduct the robustness tests, all tests are equally conducted and displayed.

Specification of Model		Data Set		
Full Sample	1	2	3	4
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	1.06E-04	1.59E-04	1.17E-04	2.99E-04
RE versus FE: Hausmann test: if p<0.05 then FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	0.003197	0.01896	0.003307	0.01894
Sub sample - exclusions based on high total assets				
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	7.22E-03	< 2.2e-16	1.05E-06
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	7.22E-03	< 2.2e-16	1.05E-06
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	2.54E-02	2.15e-05	2.53E-05	2.84E-05
RE versus FE: Hausmann test: if p<0.05 then FE.	< 2.2e-16	7.22E-03	< 2.2e-16	1.05E-06
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	8.89E-06	0.0002227	8.43E-06	0.0002132
Sub sample - exclusions based on high market capitalization				
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.002668	0.001834	0.003406	0.003393
RE versus FE: Hausmann test: if p<0.05 then FE.	0.0007479	< 2.2e-16	8.69E-07	< 2.2e-16
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.				
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	4.31E-07	0.0001365	4.34E-07	0.0001543

Source: Own Calculation

Table 23: Tests for Fixed Effects Models on Tobin's Q and Different Configurations:
For each configuration on the dependent variable Tobin's Q tests are executed to determine whether the panel data can be estimated versus a simple ordinary least square model or whether fixed effects and random effects are the better fit. Additionally the test results for heteroskedasticity and serial correlation are displayed. For the decreased subsets to conduct the robustness tests, all tests are equally conducted and displayed.

Specification of Model				
Full Sample	1	2	3	4
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	5.61E-05	5.23E-05	2.53E-05	6.86E-05
RE versus FE: Hausmann test: if p<0.05 then FE.	4.51E-09	6.45E-16	< 2.2e-16	2.12E-09
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Sub sample - exclusions based on high total assets				
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.0004779	0.001549	0.001743	0.001795
RE versus FE: Hausmann test: if p<0.05 then FE.	6.16E-08	< 2.2e-16	< 2.2e-16	5.82E-13
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	2.09E-14	8.19E-12	2.48E-10	4.38E-13
Sub sample - exclusions based on high market capitalization				
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.000311	0.0002583	1.42E-05	2.95E-05
RE versus FE: Hausmann test: if p<0.05 then FE.	1.07E-14	6.62E-05	1.05E-13	< 2.2e-16
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	< 2.2e-16	1.00E-12	4.66E-12	< 2.2e-16

Source: Own Calculation

A.0.4.2 Individual Time Effects

Table 24: Time Effects of the Fixed Effects Models on the Dependent Variable ROA:
The model is a fixed firm effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed here. The robust covariance matrix is displayed in chapter 5 in table 10. It shows different configurations of the explanatory variables on ROA.

	Dependent variable:			
	ROA			
	(1)	(2)	(3)	(4)
year 1982	-0.015^{***}	-0.015^{***}	-0.031^{***}	-0.032^{***}
	(0.003)	(0.003)	(0.004)	(0.004)
year 1983	-0.006^{***}	-0.006^{***}	-0.011^{***}	-0.012^{***}
	(0.002)	(0.002)	(0.003)	(0.003)
year 1984	-0.006^{**}	-0.006^{**}	-0.015^{***}	-0.016^{***}
	(0.003)	(0.003)	(0.004)	(0.004)
year 1985	-0.006	-0.005	-0.015^{***}	-0.016^{***}
	(0.004)	(0.004)	(0.005)	(0.005)
year 1986	-0.005	-0.005	-0.014^{***}	-0.015^{***}
	(0.004)	(0.004)	(0.005)	(0.006)
year 1987	-0.024^{***}	-0.024^{***}	-0.037^{***}	-0.038^{***}
	(0.004)	(0.004)	(0.005)	(0.005)
year 1988	-0.020^{***}	-0.020^{***}	-0.028^{***}	-0.030^{***}
	(0.004)	(0.004)	(0.006)	(0.006)
year 1989	-0.032^{***}	-0.032^{***}	-0.037^{***}	-0.039^{***}
	(0.005)	(0.005)	(0.007)	(0.007)
year 1990	-0.033^{***}	-0.033^{***}	-0.039^{***}	-0.040^{***}
	(0.005)	(0.005)	(0.008)	(0.008)
year 1991	-0.032^{***}	-0.032^{***}	-0.045^{***}	-0.046^{***}
	(0.005)	(0.005)	(0.008)	(0.008)
year 1992	-0.033^{***}	-0.033^{***}	-0.041^{***}	-0.043^{***}
	(0.005)	(0.005)	(0.008)	(0.008)
year 1993	-0.035^{***}	-0.035^{***}	-0.039^{***}	-0.041^{***}
	(0.006)	(0.006)	(0.009)	(0.009)
year 1994	-0.044^{***}	-0.044^{***}	-0.048^{***}	-0.051^{***}
	(0.006)	(0.006)	(0.009)	(0.009)
year 1995	-0.040^{***}	-0.040^{***}	-0.046^{***}	-0.049^{***}
	(0.007)	(0.007)	(0.011)	(0.010)
year 1996	-0.039^{***}	-0.039^{***}	-0.043^{***}	-0.046^{***}
	(0.007)	(0.007)	(0.010)	(0.010)
year 1997	-0.041^{***}	-0.042^{***}	-0.041^{***}	-0.045^{***}
	(0.007)	(0.007)	(0.011)	(0.010)
year 1998	-0.042^{***}	-0.042^{***}	-0.049^{***}	-0.052^{***}
	(0.008)	(0.008)	(0.014)	(0.013)
year 1999	-0.041^{***}	-0.042^{***}	-0.047^{***}	-0.050^{***}
	(0.009)	(0.009)	(0.014)	(0.013)
year 2000	-0.033^{***}	-0.033^{***}	-0.034^{**}	-0.038^{***}
	(0.009)	(0.009)	(0.015)	(0.015)
year 2001	-0.038^{***}	-0.039^{***}	-0.036^{**}	-0.042^{***}
	(0.010)	(0.010)	(0.015)	(0.014)
year 2002	-0.060^{***}	-0.060^{***}	-0.059^{***}	-0.062^{***}
	(0.009)	(0.009)	(0.014)	(0.014)
year 2003	-0.046^{***}	-0.046^{***}	-0.041^{***}	-0.045^{***}
	(0.009)	(0.009)	(0.015)	(0.015)
year 2004	-0.034^{***}	-0.034^{***}	-0.026	-0.030^{**}
	(0.010)	(0.010)	(0.016)	(0.015)
year 2005	-0.032^{***}	-0.033^{***}	-0.023	-0.028
	(0.011)	(0.011)	(0.018)	(0.017)
year 2006	-0.029^{**}	-0.029^{***}	-0.020	-0.025
	(0.011)	(0.011)	(0.018)	(0.017)
year 2007	-0.027^{**}	-0.028^{**}	-0.017	-0.023
	(0.011)	(0.011)	(0.018)	(0.017)
Observations	2,476	2,476	2,053	2,053
R^2	0.076	0.077	0.076	0.076
Adjusted R^2	0.055	0.055	0.053	0.054
F Statistic	3.977^{***}	4.024^{***}	3.206^{***}	3.222^{***}
	(df = 37; 1786)	(df = 37; 1786)	(df = 37; 1444)	(df = 37; 1444)
Note:				*p<0.1; **p<0.05; ***p<0.01
				Source: Own Calculation

Table 25: Time Effects of the Fixed Effects Models on the Dependent Variable Tobin's Q:
The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed here. The robust covariance matrix is displayed in chapter 5 in table 11. It shows different configurations of the explanatory variables on Tobin's Q.

	Dependent variable:			
	Tobin's Q			
		(2)	(3)	(4)
year 1982	0.085*** (0.018)	0.104*** (0.023)	0.083*** (0.020)	0.057*** (0.015)
year 1983	0.025 (0.016)	0.071*** (0.021)	0.043** (0.017)	0.003 (0.014)
year 1984	0.026 (0.032)	0.047 (0.031)	0.036 (0.034)	0.026 (0.031)
year 1985	0.005 (0.032)	0.014 (0.036)	0.014 (0.034)	0.010 (0.027)
year 1986	−0.048 (0.035)	−0.005 (0.042)	0.004 (0.043)	−0.031 (0.037)
year 1987	−0.050 (0.041)	0.012 (0.046)	0.025 (0.044)	−0.031 (0.038)
year 1988	−0.039 (0.050)	0.017 (0.047)	0.046 (0.050)	0.005 (0.047)
year 1989	0.015 (0.057)	0.063 (0.057)	0.071 (0.057)	0.042 (0.051)
year 1990	−0.063 (0.051)	−0.016 (0.051)	0.002 (0.060)	−0.019 (0.055)
year 1991	−0.040 (0.050)	−0.016 (0.049)	0.012 (0.068)	0.014 (0.054)
year 1992	−0.036 (0.059)	0.004 (0.063)	0.027 (0.081)	0.034 (0.060)
year 1993	−0.030 (0.058)	0.054 (0.057)	0.095 (0.069)	0.034 (0.060)
year 1994	−0.105* (0.062)	−0.053 (0.062)	−0.009 (0.076)	−0.048 (0.065)
year 1995	0.036 (0.065)	0.109* (0.065)	0.157** (0.079)	0.114* (0.065)
year 1996	0.063 (0.069)	0.174*** (0.065)	0.223*** (0.077)	0.143** (0.069)
year 1997	0.005 (0.078)	0.083 (0.078)	0.106 (0.093)	0.062 (0.080)
year 1998	0.123* (0.074)	0.231*** (0.075)	0.306*** (0.083)	0.221*** (0.072)
year 1999	0.089 (0.083)	0.228*** (0.085)	0.311*** (0.097)	0.188** (0.081)
year 2000	−0.034 (0.099)	0.037 (0.103)	0.077 (0.119)	0.057 (0.098)
year 2001	−0.068 (0.103)	0.022 (0.103)	0.070 (0.112)	0.018 (0.100)
year 2002	−0.017 (0.103)	0.096 (0.098)	0.141 (0.101)	0.056 (0.099)
year 2003	0.088 (0.104)	0.210** (0.099)	0.260** (0.107)	0.173* (0.104)
year 2004	0.138 (0.112)	0.272** (0.111)	0.317** (0.123)	0.222** (0.112)
year 2005	0.198 (0.122)	0.344*** (0.123)	0.393*** (0.141)	0.283** (0.124)
year 2006	0.134 (0.115)	0.285*** (0.110)	0.342*** (0.125)	0.228* (0.121)
year 2007	0.183 (0.122)	0.350*** (0.115)	0.417*** (0.122)	0.294** (0.118)
Observations	2,133	1,730	1,667	2,066
R^2	0.419	0.422	0.420	0.422
Adjusted R^2	0.298	0.291	0.288	0.300
F Statistic	28.814*** (df = 38; 1521)	22.927*** (df = 38; 1191)	21.765*** (df = 38; 1140)	28.237*** (df = 38; 1467)
Note:				*p<0.1; **p<0.05; ***p<0.01

Source: Own Calculation

A.0.4.3 Results of Reduced Subsets for Robustness Tests

A.0.4.3.1 Decreased Subset Based on Total Assets

TABLE 26: Different Configurations of a Fixed Effects Models on the Dependent Variable ROA with a Reduced Subset Based on Total Assets:
For the subset all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed in the appendix in table 27.

	Dependent variable:			
	ROA			
	(1)+	(2)+	(3)+	(4)+
ln.TotAss	−0.001	−0.001	−0.001	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)
ln.SalesGrowth	0.002	0.001	0.003**	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
ln.DebtGrowth	−0.002**	−0.002**	−0.002**	−0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
ln.CapexGrowth	−0.0003	−0.0003	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
DiviPayou	−0.0003***	−0.0003***	−0.0002*	−0.0002**
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
EarnDum	0.011***	0.010**	0.014***	0.013***
	(0.004)	(0.004)	(0.005)	(0.005)
DivDum	0.004	0.004	0.004	0.004
	(0.004)	(0.004)	(0.005)	(0.005)
PopGrowth	0.017***	0.018***	0.014**	0.014**
	(0.006)	(0.006)	(0.007)	(0.007)
ln.GDPPCap	−0.006	−0.002	0.003	0.014
	(0.027)	(0.028)	(0.037)	(0.038)
OECD-Aggr	−0.003*	−0.002		
	(0.002)	(0.002)		
OECD-Detail			0.001	−0.0001
			(0.002)	(0.002)
ToNumOfFirms	−0.0001		−0.020*	
	(0.009)		(0.011)	
ln.PopGrowth		−0.015		−0.020*
		(0.011)		(0.011)
Observations	2,355	2,355	1,947	1,947
R^2	0.066	0.067	0.067	0.068
Adjusted R^2	0.047	0.047	0.047	0.047
F Statistic	3.193***	3.231***	2.626***	2.643***
	(df = 37; 1677)	(df = 37; 1677)	(df = 37; 1348)	(df = 37; 1348)

Note: *p<0.1; **p<0.05; ***p<0.01
+Individual time effects prevalent and displayed in the following table.
Source: Own Calculation

Table 27: Time Effects of the Fixed Effects Models on the Dependent Variable ROA with a Reduced Subset Based on Total Assets:
For the subset all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed here. The robust covariance matrix is displayed in table 26. It shows different configurations of the explanatory variables on ROA.

	Dependent variable: ROA			
	(1)	(2)		
year 1982	-0.016^{***} (0.003)	-0.017^{***} (0.003)	-0.033^{***} (0.004)	-0.034^{***} (0.004)
year 1983	-0.006^{***} (0.002)	-0.006^{***} (0.002)	-0.012^{***} (0.003)	-0.013^{***} (0.003)
year 1984	-0.007^{**} (0.003)	-0.007^{**} (0.003)	-0.017^{***} (0.004)	-0.017^{***} (0.004)
year 1985	-0.006 (0.004)	-0.005 (0.004)	-0.016^{***} (0.005)	-0.016^{***} (0.005)
year 1986	-0.007^{*} (0.004)	-0.007^{*} (0.004)	-0.016^{***} (0.006)	-0.017^{***} (0.006)
year 1987	-0.025^{***} (0.004)	-0.026^{***} (0.004)	-0.039^{***} (0.006)	-0.040^{***} (0.006)
year 1988	-0.022^{***} (0.004)	-0.022^{***} (0.004)	-0.032^{***} (0.007)	-0.033^{***} (0.007)
year 1989	-0.033^{***} (0.005)	-0.033^{***} (0.006)	-0.041^{***} (0.008)	-0.042^{***} (0.008)
year 1990	-0.034^{***} (0.006)	-0.034^{***} (0.006)	-0.044^{***} (0.009)	-0.045^{***} (0.009)
year 1991	-0.032^{***} (0.006)	-0.032^{***} (0.006)	-0.049^{***} (0.008)	-0.050^{***} (0.009)
year 1992	-0.034^{***} (0.006)	-0.034^{***} (0.006)	-0.046^{***} (0.008)	-0.048^{***} (0.009)
year 1993	-0.037^{***} (0.007)	-0.038^{***} (0.007)	-0.045^{***} (0.009)	-0.047^{***} (0.010)
year 1994	-0.046^{***} (0.006)	-0.046^{***} (0.007)	-0.055^{***} (0.009)	-0.057^{***} (0.010)
year 1995	-0.041^{***} (0.007)	-0.041^{***} (0.007)	-0.053^{***} (0.011)	-0.056^{***} (0.011)
year 1996	-0.040^{***} (0.007)	-0.040^{***} (0.007)	-0.051^{***} (0.010)	-0.054^{***} (0.011)
year 1997	-0.044^{***} (0.007)	-0.044^{***} (0.008)	-0.051^{***} (0.010)	-0.054^{***} (0.011)
year 1998	-0.047^{***} (0.008)	-0.047^{***} (0.008)	-0.062^{***} (0.013)	-0.064^{***} (0.013)
year 1999	-0.045^{***} (0.008)	-0.045^{***} (0.008)	-0.057^{***} (0.013)	-0.060^{***} (0.013)
year 2000	-0.034^{***} (0.009)	-0.034^{***} (0.009)	-0.042^{***} (0.014)	-0.046^{***} (0.015)
year 2001	-0.041^{***} (0.009)	-0.042^{***} (0.010)	-0.047^{***} (0.014)	-0.052^{***} (0.015)
year 2002	-0.061^{***} (0.009)	-0.061^{***} (0.009)	-0.067^{***} (0.014)	-0.070^{***} (0.014)
year 2003	-0.048^{***} (0.009)	-0.048^{***} (0.010)	-0.052^{***} (0.015)	-0.056^{***} (0.015)
year 2004	-0.038^{***} (0.010)	-0.038^{***} (0.010)	-0.038^{**} (0.015)	-0.043^{***} (0.016)
year 2005	-0.036^{***} (0.011)	-0.037^{***} (0.012)	-0.036^{**} (0.017)	-0.041^{**} (0.017)
year 2006	-0.037^{***} (0.011)	-0.037^{***} (0.011)	-0.038^{**} (0.016)	-0.043^{**} (0.017)
year 2007	-0.033^{***} (0.011)	-0.034^{***} (0.011)	-0.034^{**} (0.017)	-0.039^{**} (0.017)
Observations	2,355	2,355	1,947	1,947
R^2	0.066	0.067	0.067	0.068
Adjusted R^2	0.047	0.047	0.047	0.047
F Statistic	3.193^{***} (df = 37; 1677)	3.231^{***} (df = 37; 1677)	2.626^{***} (df = 37; 1348)	2.643^{***} (df = 37; 1348)
Note:				*p<0.1; **p<0.05; ***p<0.01 *Source: Own Calculation*

Table 28: Different Configurations of a Fixed Effects Models on the Dependent Variable Tobin's Q with a Reduced Subset Based on Total Assets: For the subset all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed in the appendix in table 29.

	Dependent variable:			
	TQ			
	(1)$^{+}$	(2)$^{+}$	(3)$^{+}$	(4)$^{+}$
ln.TotAss	-0.062^{***}	-0.055^{**}	-0.074^{***}	-0.064^{***}
	(0.022)	(0.022)	(0.018)	(0.018)
ln.SalesGrowth	0.041^{***}	0.035^{***}	0.043^{***}	0.033^{***}
	(0.011)	(0.008)	(0.011)	(0.008)
ln.DebtGrowth	-0.012^{*}	-0.014^{**}	-0.015^{**}	-0.016^{**}
	(0.007)	(0.007)	(0.007)	(0.006)
ln.CapexGrowth	0.007	0.003	0.009^{*}	0.003
	(0.005)	(0.004)	(0.005)	(0.004)
ln.BookToPrice	-0.629^{***}	-0.618^{***}	-0.615^{***}	-0.620^{***}
	(0.051)	(0.047)	(0.053)	(0.051)
DiviPayou	-0.001^{**}	-0.001^{***}		
	(0.0004)	(0.0003)		
lag(DiviPayou)			-0.001^{***}	-0.001^{***}
			(0.0005)	(0.0004)
EarnDum	0.065	0.045	0.078^{*}	0.039
	(0.041)	(0.037)	(0.045)	(0.035)
DivDum	−0.002	−0.003	−0.021	−0.013
	(0.023)	(0.019)	(0.027)	(0.023)
PopGrowth	0.165^{***}	0.148^{***}		
	(0.033)	(0.035)		
ln.PopGrowth			0.041^{***}	0.016
			(0.012)	(0.016)
ln.GDPPCap	−0.389	−0.248	−0.391	−0.298
	(0.246)	(0.248)	(0.281)	(0.280)
OECD-Detail	0.031^{**}		0.030^{**}	
	(0.013)		(0.012)	
OECD-Aggr		0.040^{*}		0.030
		(0.021)		(0.019)
ToNumOfFirms	−0.117	−0.086		
	(0.131)	(0.118)		
ln.PopGrowth			−0.191	-0.226^{**}
			(0.121)	(0.115)
Observations	1,634	2,023	1,568	1,954
R^2	0.384	0.385	0.378	0.387
Adjusted R^2	0.260	0.271	0.253	0.271
F Statistic	18.118^{***} (df = 38; 1104)	23.460^{***} (df = 38; 1424)	16.821^{***} (df = 38; 1051)	22.751^{***} (df = 38; 1369)

Note: *p<0.1; **p<0.05; ***p<0.01

$^{+}$Individual time effects prevalent and displayed in the following table.

Source: Own Calculation

TABLE 29: Time Effects of the Fixed Effects Models on the Dependent Variable Tobin's Q with a Reduced Subset Based on Total Assets:
For the subset all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed here. The robust covariance matrix is displayed in table 28.

	Dependent variable:			
	TQ			
	(1)	(2)	(3)	(4)
year 1982	0.077***	0.063***	0.065***	0.042***
	(0.020)	(0.017)	(0.018)	(0.015)
year 1983	0.061***	0.017	0.033*	−0.006
	(0.019)	(0.015)	(0.018)	(0.014)
year 1984	0.026	0.005	0.016	0.004
	(0.033)	(0.033)	(0.034)	(0.032)
year 1985	−0.007	−0.019	−0.014	−0.019
	(0.034)	(0.033)	(0.034)	(0.032)
year 1986	−0.005	−0.061	0.0002	−0.044
	(0.039)	(0.037)	(0.042)	(0.041)
year 1987	−0.036	−0.094**	0.016	−0.049
	(0.045)	(0.043)	(0.048)	(0.046)
year 1988	−0.020	−0.058	−0.011	−0.043
	(0.051)	(0.054)	(0.057)	(0.058)
year 1989	0.031	0.0002	0.037	0.018
	(0.060)	(0.062)	(0.065)	(0.064)
year 1990	−0.058	−0.089	−0.041	−0.051
	(0.056)	(0.059)	(0.066)	(0.067)
year 1991	−0.065	−0.066	−0.011	−0.008
	(0.058)	(0.059)	(0.074)	(0.068)
year 1992	−0.036	−0.060	0.003	0.001
	(0.070)	(0.068)	(0.084)	(0.073)
year 1993	−0.0001	−0.061	0.048	−0.003
	(0.062)	(0.066)	(0.075)	(0.074)
year 1994	−0.107	−0.133*	−0.062	−0.088
	(0.066)	(0.070)	(0.086)	(0.084)
year 1995	0.036	0.004	0.076	0.057
	(0.067)	(0.072)	(0.088)	(0.083)
year 1996	0.105	0.039	0.159*	0.097
	(0.065)	(0.076)	(0.085)	(0.087)
year 1997	0.002	−0.030	0.026	−0.001
	(0.076)	(0.083)	(0.099)	(0.099)
year 1998	0.142*	0.079	0.218**	0.155
	(0.075)	(0.085)	(0.087)	(0.098)
year 1999	0.153**	0.059	0.224**	0.127
	(0.077)	(0.087)	(0.096)	(0.099)
year 2000	−0.003	−0.035	0.030	0.021
	(0.091)	(0.101)	(0.119)	(0.117)
year 2001	−0.066	−0.104	−0.026	−0.058
	(0.101)	(0.109)	(0.121)	(0.125)
year 2002	−0.003	−0.059	0.042	−0.024
	(0.097)	(0.111)	(0.117)	(0.130)
year 2003	0.097	0.038	0.144	0.083
	(0.089)	(0.107)	(0.113)	(0.127)
year 2004	0.175*	0.100	0.211*	0.136
	(0.099)	(0.116)	(0.125)	(0.135)
year 2005	0.253**	0.169	0.292**	0.202
	(0.108)	(0.123)	(0.138)	(0.147)
year 2006	0.165	0.080	0.215*	0.125
	(0.103)	(0.122)	(0.129)	(0.151)
year 2007	0.231**	0.134	0.291**	0.192
	(0.112)	(0.133)	(0.135)	(0.153)
Observations	1,634	2,023	1,568	1,954
R^2	0.384	0.385	0.378	0.387
Adjusted R^2	0.260	0.271	0.253	0.271
F Statistic	18.118***	23.460***	16.821***	22.751***
	(df = 38; 1104)	(df = 38; 1424)	(df = 38; 1051)	(df = 38; 1369)
Note:				*p<0.1; **p<0.05; ***p<0.01
				Source: Own Calculation

A.0.4.3.2 Decreased Subset Based on Market Capitalization

TABLE 30: Different Configurations of a Fixed Effects Models on the Dependent Variable ROA with a Reduced Subset Based on Market Capitalization:
For the subset all firms with high market capitalization are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed in table 31.

	Dependent variable:			
	ROA			
	(1)+	(2)+	(3)+	(4)+
ln.TotAss	−0.004	−0.004	−0.004	−0.004
	(0.004)	(0.004)	(0.004)	(0.004)
ln.SalesGrowth	0.0005	0.0003	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
ln.DebtGrowth	−0.003***	−0.003***	−0.003***	−0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
ln.CapexGrowth	−0.001	−0.001	−0.0001	−0.0001
	(0.001)	(0.001)	(0.001)	(0.001)
DiviPayou	−0.0002**	−0.0002**	−0.0001	−0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
EarnDum	0.007	0.006	0.009	0.009*
	(0.004)	(0.004)	(0.006)	(0.005)
DivDum	0.007	0.007	0.008	0.007
	(0.005)	(0.005)	(0.006)	(0.006)
PopGrowth	0.019***	0.020***	0.014**	0.014**
	(0.007)	(0.007)	(0.006)	(0.007)
ln.GDPPCap	−0.017	−0.009	−0.015	0.003
	(0.034)	(0.032)	(0.042)	(0.041)
OECD-Aggr	−0.003	−0.003		
	(0.003)	(0.002)		
OECD-Detail			0.001	0.0002
			(0.002)	(0.002)
ToNumOfFirms	−0.006		−0.024***	
	(0.010)		(0.009)	
ln.PopGrowth		−0.021		−0.020
		(0.013)		(0.013)
Observations	1,874	1,874	1,593	1,593
R^2	0.067	0.068	0.077	0.077
Adjusted R^2	0.044	0.045	0.049	0.049
F Statistic	2.937***	2.992***	2.833***	2.831***
	(df = 30; 1224)	(df = 30; 1224)	(df = 30; 1022)	(df = 30; 1022)

Note: *p<0.1; **p<0.05; ***p<0.01
+Individual time effects prevalent and displayed in the following table.
Source: Own Calculation

TABLE 31: Time Effects of the Fixed Effects Models on the Dependent Variable ROA with a Reduced Subset Based on Market Capitalization:
For the subset all firms with high market capitalization are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed here. The robust covariance matrix is displayed in table 30. It shows different configurations of the explanatory variables on ROA.

	Dependent variable:			
	ROA – return on assets			
	(1)	(2)		
year 1989	-0.014^{***}	-0.014^{***}	-0.012^{***}	-0.012^{***}
	(0.003)	(0.003)	(0.003)	(0.003)
year 1990	-0.015^{***}	-0.016^{***}	-0.015^{***}	-0.015^{***}
	(0.004)	(0.004)	(0.004)	(0.004)
year 1991	-0.014^{***}	-0.014^{***}	-0.019^{***}	-0.018^{***}
	(0.003)	(0.003)	(0.003)	(0.003)
year 1992	-0.013^{***}	-0.014^{***}	-0.015^{***}	-0.015^{***}
	(0.004)	(0.004)	(0.003)	(0.003)
year 1993	-0.016^{***}	-0.017^{***}	-0.014^{***}	-0.014^{***}
	(0.005)	(0.005)	(0.005)	(0.004)
year 1994	-0.024^{***}	-0.025^{***}	-0.021^{***}	-0.022^{***}
	(0.005)	(0.005)	(0.005)	(0.005)
year 1995	-0.018^{***}	-0.019^{***}	-0.018^{**}	-0.020^{***}
	(0.006)	(0.006)	(0.007)	(0.007)
year 1996	-0.014^{**}	-0.016^{***}	-0.013^{**}	-0.015^{**}
	(0.006)	(0.006)	(0.007)	(0.006)
year 1997	-0.018^{***}	-0.020^{***}	-0.014^{*}	-0.016^{**}
	(0.007)	(0.006)	(0.007)	(0.007)
year 1998	-0.019^{***}	-0.020^{***}	-0.021^{**}	-0.023^{**}
	(0.007)	(0.007)	(0.010)	(0.010)
year 1999	-0.020^{**}	-0.021^{***}	-0.022^{**}	-0.024^{**}
	(0.008)	(0.008)	(0.010)	(0.010)
year 2000	-0.012	-0.014^{**}	-0.015	-0.018
	(0.008)	(0.007)	(0.013)	(0.012)
year 2001	-0.021^{**}	-0.024^{**}	-0.015	-0.020^{*}
	(0.010)	(0.009)	(0.013)	(0.012)
year 2002	-0.035^{***}	-0.036^{***}	-0.030^{***}	-0.033^{***}
	(0.009)	(0.008)	(0.011)	(0.011)
year 2003	-0.020^{**}	-0.022^{**}	-0.012	-0.016
	(0.009)	(0.009)	(0.012)	(0.012)
year 2004	-0.006	-0.008	0.006	0.001
	(0.010)	(0.010)	(0.014)	(0.013)
year 2005	-0.005	-0.008	0.008	0.003
	(0.012)	(0.012)	(0.016)	(0.015)
year 2006	-0.003	-0.005	0.009	0.003
	(0.013)	(0.012)	(0.016)	(0.015)
year 2007	0.006	0.004	0.018	0.012
	(0.014)	(0.013)	(0.017)	(0.016)
Observations	1,874	1,874	1,593	1,593
R^2	0.067	0.068	0.077	0.077
Adjusted R^2	0.044	0.045	0.049	0.049
F Statistic	2.937^{***}	2.992^{***}	2.833^{***}	2.831^{***}
	(df = 30; 1224)	(df = 30; 1224)	(df = 30; 1022)	(df = 30; 1022)
Note:				*p<0.1; **p<0.05; ***p<0.01
				Source: Own Calculation

Table 32: Different Configurations of a Fixed Effects Models on the Dependent Variable Tobin's Q with a Reduced Subset Based on Market Capitalization:
For the subset all firms with high market capitalization are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed in the appendix in table 33.

	Dependent variable:			
	TQ			
	(1)+	(2)+	(3)+	(4)+
ln.TotAss	-0.126^{***}	-0.127^{***}	-0.128^{***}	-0.129^{***}
	(0.039)	(0.037)	(0.046)	(0.041)
ln.SalesGrowth	0.044^{***}	0.035^{***}	0.044^{***}	0.034^{***}
	(0.011)	(0.009)	(0.010)	(0.008)
ln.DebtGrowth	-0.022^{**}	-0.024^{**}	-0.023^{***}	-0.028^{***}
	(0.011)	(0.010)	(0.009)	(0.009)
ln.CapexGrowth	−0.007	−0.006	−0.002	−0.004
	(0.010)	(0.009)	(0.011)	(0.009)
ln.BookToPrice	-0.679^{***}	-0.680^{***}	-0.666^{***}	-0.672^{***}
	(0.065)	(0.065)	(0.079)	(0.076)
DiviPayou	−0.0003	−0.0004		
	(0.001)	(0.0004)		
lag(DiviPayou)			−0.001	−0.001
			(0.001)	(0.001)
EarnDum	0.021	0.008	0.029	−0.002
	(0.035)	(0.031)	(0.030)	(0.023)
DivDum	0.012	0.004	0.011	0.013
	(0.034)	(0.030)	(0.033)	(0.029)
PopGrowth	0.064^{**}	0.077		
	(0.032)	(0.049)		
ln.PopGrowth			0.018	0.008
			(0.016)	(0.016)
ln.GDPPCap	−0.397	−0.286	-0.790^{**}	-0.642^{*}
	(0.315)	(0.344)	(0.385)	(0.368)
OECD-Detail	0.004		0.011	
	(0.015)		(0.016)	
OECD-Aggr		0.015		0.021
		(0.035)		(0.033)
ToNumOfFirms	0.175	0.108		
	(0.171)	(0.175)		
ln.PopGrowth			−0.121	−0.174
			(0.164)	(0.143)
Observations	1,370	1,642	1,258	1,514
R^2	0.440	0.437	0.432	0.439
Adjusted R^2	0.279	0.284	0.265	0.278
F Statistic	21.986^{***}	26.709^{***}	19.580^{***}	24.967^{***}
	(df = 31; 867)	(df = 31; 1067)	(df = 30; 772)	(df = 30; 958)
Note:				*p<0.1; **p<0.05; ***p<0.01

+Individual time effects prevalent and displayed in the following table.

Source: Own Calculation

TABLE 33: Time Effects of the Fixed Effects Models on the Dependent Variable Tobin's Q with a Reduced Subset Based on Market Capitalization: For the subset all firms with high market capitalization are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed here. The robust covariance matrix is displayed in table 32.

	Dependent variable:			
	TQ			
	(1)	(2)	(3)	(4)
year 1989	0.045**	0.053***		
	(0.021)	(0.018)		
year 1990	−0.038**	−0.024	−0.068***	−0.054***
	(0.018)	(0.018)	(0.021)	(0.019)
year 1991	−0.019	0.011	−0.045	−0.005
	(0.031)	(0.029)	(0.029)	(0.022)
year 1992	−0.008	0.017	−0.044	0.012
	(0.032)	(0.031)	(0.042)	(0.027)
year 1993	0.055	0.032	0.046	0.022
	(0.035)	(0.035)	(0.034)	(0.030)
year 1994	−0.080*	−0.061	−0.072	−0.067
	(0.042)	(0.040)	(0.048)	(0.042)
year 1995	0.093*	0.098*	0.109*	0.109*
	(0.048)	(0.051)	(0.057)	(0.056)
year 1996	0.154***	0.131**	0.181***	0.150**
	(0.049)	(0.058)	(0.062)	(0.066)
year 1997	0.075	0.082	0.087	0.085
	(0.069)	(0.075)	(0.088)	(0.087)
year 1998	0.217***	0.200***	0.289***	0.247***
	(0.069)	(0.074)	(0.086)	(0.079)
year 1999	0.182**	0.143*	0.272***	0.202**
	(0.071)	(0.086)	(0.083)	(0.092)
year 2000	−0.050	−0.037	−0.030	−0.005
	(0.091)	(0.092)	(0.109)	(0.104)
year 2001	0.020	0.027	0.123	0.094
	(0.078)	(0.100)	(0.113)	(0.118)
year 2002	0.083	0.074	0.118	0.070
	(0.088)	(0.105)	(0.111)	(0.122)
year 2003	0.192**	0.179	0.249**	0.215
	(0.093)	(0.115)	(0.125)	(0.140)
year 2004	0.266**	0.242*	0.339**	0.296*
	(0.104)	(0.125)	(0.145)	(0.157)
year 2005	0.374***	0.342**	0.465***	0.403**
	(0.116)	(0.136)	(0.167)	(0.169)
year 2006	0.281**	0.251*	0.374**	0.318*
	(0.115)	(0.142)	(0.175)	(0.182)
year 2007	0.341***	0.311**	0.453***	0.404**
	(0.119)	(0.152)	(0.169)	(0.188)
Observations	1,370	1,642	1,258	1,514
R^2	0.440	0.437	0.432	0.439
Adjusted R^2	0.279	0.284	0.265	0.278
F Statistic	21.986***	26.709***	19.580***	24.967***
	(df = 31; 867)	(df = 31; 1067)	(df = 30; 772)	(df = 30; 958)
Note:				*p<0.1; **p<0.05; ***p<0.01
				Source: Own Calculation

A.0.4.4 Variance Inflation Factors

Table 34: Variance Inflation Factors for Different Configurations of the Main Set:
VIFS test for multicollinearity within the configurations. High multicollinearity is assumed for values over 5.0

Full Set												
ROA												
Full Set (1)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	ToNumOf-Fir.	
	1.25	1.45	1.44	1.41	1.48	1.74	1.51	1.21	1.97	1.87	1.33	
Full Set (2)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	ToNumOf-Fir.	
	1.30	1.42	1.42	1.41	1.48	1.69	1.48	1.25	1.50	1.57	1.34	
Full Set (3)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.25	1.45	1.44	1.41	1.48	1.75	1.52	1.26	2.07	1.83	1.40	
Full Set (4)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	HHI	
	1.30	1.42	1.42	1.41	1.48	1.71	1.48	1.29	1.52	1.54	1.38	
Tobin's Q												
Full Set (1)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookTPrice	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	ToNumOf-Fir.
	1.28	1.46	1.45	1.39	1.18	1.55	1.90	1.59	1.22	1.95	1.75	1.26
Full Set (2)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookTPrice	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	ToNumOf-Fir.
	1.34	1.42	1.41	1.40	1.18	1.58	1.85	1.54	1.30	1.49	1.51	1.29
Full Set (3)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookTPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.34	1.43	1.42	1.41	1.18	1.60	1.85	1.54	1.23	1.49	1.46	1.26
Full Set (4)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookTPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.27	1.47	1.46	1.40	1.19	1.56	1.89	1.59	1.20	2.11	1.84	1.28

Source: Own Calculation

Table 35: Variance Inflation Factors for Different Configurations Reduced Subsets Based on Total Assets: VIFS test for multicollinearity within the configurations. High multicollinearity is assumed for values over 5.0

Full Set												
ROA												
Subset (1)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	ToNumOf-Fir.	
	1.25	1.46	1.44	1.41	1.50	1.75	1.52	1.20	1.98	1.90	1.35	
Subset (2)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	ToNumOf-Fir.	
	1.30	1.42	1.41	1.40	1.50	1.68	1.48	1.24	1.50	1.58	1.35	
Subset (3)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.25	1.46	1.44	1.41	1.51	1.76	1.52	1.25	2.08	1.85	1.41	
Subset (4)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	HHI	
	1.29	1.42	1.41	1.40	1.50	1.70	1.48	1.28	1.53	1.54	1.39	
Tobin's Q												
Subset (1)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	ToNumOf-Fir.
	1.27	1.47	1.45	1.38	1.19	1.58	1.91	1.60	1.22	1.97	1.78	1.27
Subset (2)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	ToNumOf-Fir.
	1.33	1.42	1.40	1.38	1.19	1.61	1.85	1.54	1.29	1.50	1.52	1.30
Subset(3)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.32	1.43	1.41	1.39	1.19	1.62	1.84	1.54	1.22	1.50	1.48	1.26
Subset(4)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.26	1.48	1.46	1.40	1.20	1.59	1.91	1.60	1.19	2.12	1.87	1.28

Source: Own Calculation

Table 36: Variance Inflation Factors for Different Configurations Reduced Subsets Based on Market Capitalization: VIFS test for multicollinearity within the configurations. High multicollinearity is assumed for values over 5.0

Full Set

ROA

Subset(1)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DiviPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	ToNumOf-Fir.
(1)	1.29	1.47	1.44	1.40	1.51	1.69	1.34	1.16	1.68	1.53	1.28
Subset (2)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DiviPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	ToNumOf-Fir.
	1.34	1.42	1.42	1.39	1.48	1.67	1.36	1.21	1.37	1.44	1.27
Subset (3)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DiviPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.29	1.47	1.44	1.40	1.51	1.72	1.34	1.20	1.77	1.52	1.41
Subset (4)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DiviPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.34	1.42	1.42	1.39	1.49	1.70	1.36	1.24	1.41	1.42	1.36

Tobin's Q

Subset (1)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	DiviPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	ToNumOf-Firms
	1.35	1.46	1.45	1.38	1.13	1.54	1.86	1.39	1.21	1.65	1.49	1.23
Subset (2)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	DiviPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECDDetail	ToNumOf-Firms
	1.40	1.39	1.42	1.37	1.15	1.54	1.85	1.40	1.30	1.37	1.44	1.25
Subset (3)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DiviPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.40	1.40	1.43	1.38	1.15	1.54	1.85	1.39	1.23	1.37	1.40	1.25
Subset(4)	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DiviPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.34	1.48	1.47	1.39	1.14	1.53	1.85	1.38	1.19	1.76	1.54	1.28

Source: Own Calculation

A.0.5 Additional Empirical Data for Subsets of Sectors

A.0.5.1 Empirical Tests

TABLE 37: Tests for Fixed Effects Models on ROA for Subsets of Sectors: For each sector on the dependent variable ROA tests are executed to determine whether the panel data can be estimated versus a simple ordinary least square model or whether fixed effects and random effects are the better fit. Additionally the test results for heteroskedasticity and serial correlation are displayed. For the decreased subsets to conduct the robustness tests, all tests are equally conducted and displayed.

	Firms active in telecommunication	Firms active in transport	Firms active in energy	Firms active in electricity	Firms active in oil and gas	Firms active in several sectors
Subsamples based on the total set						
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.267	0.247	9.26E-07	0.0002443	3.89E-06	0.01268
RE versus FE: Hausmann test: if p<0.05 then FE.	5.85E-10	0.00382	< 2.2e-16	< 2.2e-16	4.69E-13	1.85E-11
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	0.02233	0.537	0.04001	0.1502	0.01513	0.06633
Sub samples - exclusions per sector based on high total assets						
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.302	0.2523	0.000235	0.0009261	0.0004437	0.004995
RE versus FE: Hausmann test: if p<0.05 then FE.	7.51E-09	< 2.2e-16	< 2.2e-16	< 2.2e-16	7.08E-10	3.62E-09
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	0.02918	0.4054	0.0001647	0.1241	3.55E-05	0.09167

Source: Own Calculation

TABLE 38: Tests for Fixed Effects Models on Tobin's Q for Subsets of Sectors: For each sector on the dependent variable Tobin's Q tests are executed to determine whether the panel data can be estimated versus a simple ordinary least square model or whether fixed effects and random effects are the better fit. Additionally the test results for heteroskedasticity and serial correlation are displayed. For the decreased subsets to conduct the robustness tests, all tests are equally conducted and displayed.

Firms active in telecommunication	Firms active in transport	Firms active in energy	Firms active in electricity	Firms active in oil and gas	Firms active in several sectors	
Subsamples based on the total set						
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	2.36E-14	3.01E-10	< 2.2e-16	< 2.2e-16	< 2.2e-16	0.002071
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.4092	0.03777	0.01314	5.34E-05	0.1708	9.82E-09
RE versus FE: Hausmann test: if p<0.05 then FE.	0.0004226	0.01132	< 2.2e-16	3.38E-09	9.71E-08	0.005294
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	2.37E-05	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	1.66E-05	0.001491	3.18E-07	0.0006977	2.77E-06	0.343
Sub samples - exclusions per sector based on high total assets						
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	5.56E-13	7.18E-08	1.19E-07	< 2.2e-16	< 2.2e-16	0.0007502
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.5729	0.0998	0.03652	0.0009307	0.2946	2.88E-08
RE versus FE: Hausmann test: if p<0.05 then FE.	0.004571	0.000474	1.19E-07	< 2.2e-16	< 2.2e-16	0.03467
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	0.0001935	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	0.001304	0.001438	1.49E-07	0.0008643	2.55E-06	0.1079

Source: Own Calculation

A.0.5.2 Individual Fixed Time Effects

TABLE 39: Time Effects of the Fixed Effects Models on the Dependent Variable ROA for Sectors:
The model is a fixed firm effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all the subsets energy, electricity, oil & gas and multis individual time effects are identified and displayed here. The robust covariance matrix is displayed in chapter 5 in table 12.

	Dependent variable:			
	ROA			
	(Energy)	(Electricity)	(Oil& Gas)	(Multis)
year 1982	-0.031^{***}	-0.007^{*}	-0.044^{***}	0.008^{**}
	(0.004)	(0.003)	(0.006)	(0.003)
year 1983	-0.007^{***}	0.011^{***}	-0.014^{**}	0.011^{***}
	(0.003)	(0.004)	(0.006)	(0.002)
year 1984	-0.009^{*}	−0.002	0.003	0.020^{***}
	(0.005)	(0.007)	(0.007)	(0.007)
year 1985	-0.013^{**}	0.001	−0.008	0.016^{*}
	(0.006)	(0.008)	(0.009)	(0.008)
year 1986	−0.005	−0.002	0.009	0.015
	(0.007)	(0.009)	(0.009)	(0.010)
year 1987	-0.037^{***}	−0.005	-0.052^{***}	0.010
	(0.006)	(0.011)	(0.008)	(0.011)
year 1988	-0.029^{***}	-0.025^{**}	−0.011	0.002
	(0.006)	(0.011)	(0.009)	(0.013)
year 1989	-0.040^{***}	-0.041^{***}	-0.022^{**}	−0.008
	(0.006)	(0.014)	(0.009)	(0.014)
year 1990	-0.051^{***}	-0.052^{***}	-0.032^{***}	−0.003
	(0.008)	(0.017)	(0.010)	(0.015)
year 1991	-0.052^{***}	-0.052^{***}	-0.039^{***}	−0.0004
	(0.008)	(0.017)	(0.010)	(0.012)
year 1992	-0.049^{***}	-0.060^{***}	-0.020^{*}	−0.008
	(0.008)	(0.017)	(0.012)	(0.013)
year 1993	-0.054^{***}	-0.060^{***}	-0.033^{***}	−0.009
	(0.009)	(0.018)	(0.012)	(0.015)
year 1994	-0.065^{***}	-0.076^{***}	-0.036^{***}	−0.014
	(0.008)	(0.021)	(0.011)	(0.017)
year 1995	-0.064^{***}	-0.068^{***}	-0.035^{***}	−0.017
	(0.009)	(0.020)	(0.013)	(0.019)
year 1996	-0.060^{***}	-0.064^{***}	-0.026^{*}	−0.023
	(0.009)	(0.019)	(0.014)	(0.021)
year 1997	-0.071^{***}	-0.099^{***}	-0.031^{**}	−0.025
	(0.010)	(0.027)	(0.014)	(0.022)
year 1998	-0.075^{***}	-0.071^{***}	-0.051^{***}	−0.016
	(0.010)	(0.022)	(0.018)	(0.025)
year 1999	-0.073^{***}	-0.078^{***}	-0.031^{*}	−0.025
	(0.011)	(0.022)	(0.019)	(0.028)
year 2000	-0.048^{***}	-0.080^{***}	0.007	−0.026
	(0.012)	(0.023)	(0.021)	(0.029)
year 2001	-0.067^{***}	-0.082^{***}	−0.015	−0.027
	(0.012)	(0.024)	(0.021)	(0.031)
year 2002	-0.085^{***}	-0.086^{***}	-0.041^{**}	−0.048
	(0.012)	(0.023)	(0.019)	(0.031)
year 2003	-0.068^{***}	-0.098^{***}	−0.009	−0.044
	(0.013)	(0.025)	(0.022)	(0.032)
year 2004	-0.066^{***}	-0.104^{***}	−0.002	−0.033
	(0.013)	(0.026)	(0.023)	(0.034)
year 2005	-0.053^{***}	-0.107^{***}	0.020	−0.040
	(0.015)	(0.027)	(0.025)	(0.035)
year 2006	-0.055^{***}	-0.104^{***}	0.022	−0.043
	(0.015)	(0.030)	(0.026)	(0.037)
year 2007	-0.063^{***}	-0.105^{***}	0.011	−0.032
	(0.016)	(0.031)	(0.026)	(0.037)
Observations	1,402	472	930	349
R^2	0.126	0.277	0.163	0.556
Adjusted R^2	0.088	0.185	0.109	0.402
F Statistic	3.810^{***}	3.267^{***}	3.280^{***}	8.532^{***}
	(df = 37; 975)	(df = 37; 315)	(df = 37; 623)	(df = 37; 252)
Note:				*p<0.1; **p<0.05; ***p<0.01

Source: Own Calculation

TABLE 40: Time Effects of the Fixed Effects Models on the Dependent Variable Tobin's Q for Sectors:
The model is a fixed firm effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all the subsets energy, electricity and multis individual time effects are identified and displayed here. The robust covariance matrix is displayed in chapter 5 in table 13.

	Dependent variable: Tobins's Q		
	(Energy)	(Electricity)	(Multis)
year 1982	0.082*** (0.023)	−0.042*** (0.015)	−0.065* (0.035)
year 1983	0.046** (0.020)	−0.071*** (0.017)	−0.069*** (0.014)
year 1984	−0.012 (0.037)	−0.005 (0.048)	0.182* (0.101)
year 1985	−0.084* (0.049)	−0.034 (0.056)	0.216 (0.135)
year 1986	−0.045 (0.054)	−0.026 (0.061)	0.186 (0.160)
year 1987	−0.023 (0.069)	−0.018 (0.074)	0.179 (0.176)
year 1988	−0.074 (0.074)	−0.058 (0.069)	0.304 (0.226)
year 1989	−0.031 (0.080)	−0.019 (0.083)	0.418 (0.254)
year 1990	−0.073 (0.071)	−0.049 (0.080)	0.379 (0.254)
year 1991	−0.071 (0.090)	−0.018 (0.098)	0.427* (0.241)
year 1992	−0.040 (0.094)	−0.022 (0.095)	0.413 (0.261)
year 1993	0.013 (0.091)	−0.014 (0.089)	0.400 (0.277)
year 1994	−0.059 (0.093)	−0.065 (0.099)	0.394 (0.308)
year 1995	0.057 (0.100)	−0.030 (0.099)	0.489 (0.328)
year 1996	0.141 (0.103)	0.039 (0.098)	0.495 (0.361)
year 1997	0.068 (0.120)	0.091 (0.106)	0.641 (0.393)
year 1998	0.014 (0.119)	0.049 (0.105)	0.739* (0.423)
year 1999	0.035 (0.126)	0.001 (0.115)	0.630 (0.462)
year 2000	0.024 (0.126)	0.150 (0.118)	0.805 (0.490)
year 2001	−0.088 (0.128)	−0.074 (0.123)	0.690 (0.507)
year 2002	0.016 (0.142)	0.036 (0.117)	0.647 (0.509)
year 2003	0.090 (0.136)	0.085 (0.118)	0.798 (0.521)
year 2004	0.118 (0.151)	0.088 (0.133)	0.871 (0.559)
year 2005	0.219 (0.168)	0.178 (0.139)	0.850 (0.573)
year 2006	0.168 (0.169)	0.191 (0.138)	0.970 (0.604)
year 2007	0.243 (0.180)	0.159 (0.143)	0.934 (0.605)
Observations	1,153	348	309
R^2	0.442	0.766	0.784
Adjusted R^2	0.301	0.495	0.558
F Statistic	16.371*** (df = 38; 785)	19.412*** (df = 38; 225)	20.970*** (df = 38; 220)
Note:	*p<0.1; **p<0.05; ***p<0.01 *Source: Own Calculation*		

A.0.5.3 Results of Decreased Subsets for Robustness Tests

TABLE 41: Fixed Effects Models for Subsets of Sectors on the Dependent Variable ROA with Reduced Subsets Based on Total Assets:
For the subsets for each sector all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For the sectors energy, electricity, oil& gas and multis individual time effects are identified and displayed in the appendix in table 42.

	Dependent variable:					
	ROA – return on assets					
	(Telecomm.)	(Transport)	(Energy$^+$)	(Electricity$^+$)	(Oil& Gas$^+$)	(Multis$^+$)
ln.TotAss	0.001	-0.031^{***}	0.003	-0.008^{**}	0.003	-0.019^{***}
	(0.007)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)
ln.SalesGrowth	-0.009^{**}	0.002	0.005^{***}	0.002	0.006^{***}	0.0004
	(0.004)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)
ln.DebtGrowth	-0.003	-0.001	-0.003^{**}	-0.001	-0.003^{**}	-0.001
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
ln.CapexGrowth	0.003	0.001	-0.0004	-0.0001	-0.0002	-0.001
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
DiviPayou	0.0004^{*}	-0.0003^{**}	-0.0003^{***}	-0.0001^{**}	-0.0004^{***}	-0.0002^{**}
	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
EarnDum	0.024^{**}	-0.003	0.003	-0.0004	0.003	-0.004
	(0.010)	(0.008)	(0.005)	(0.008)	(0.006)	(0.005)
DivDum	0.003	0.013	0.003	0.007^{*}	0.002	0.008^{**}
	(0.011)	(0.010)	(0.005)	(0.004)	(0.007)	(0.004)
PopGrowth	0.019	0.029^{**}	0.014^{***}	0.035^{***}	0.013^{*}	0.002
	(0.023)	(0.011)	(0.005)	(0.012)	(0.007)	(0.009)
ln.GDPPCap	0.054	0.059^{*}	0.038	0.148^{**}	-0.065	0.071
	(0.048)	(0.032)	(0.039)	(0.067)	(0.053)	(0.096)
OECD-Aggr	0.003	-0.002	-0.002	-0.015^{***}	0.009	-0.027^{***}
	(0.007)	(0.005)	(0.004)	(0.004)	(0.006)	(0.005)
ln.PopGrowth	0.024	-0.049^{*}	-0.012	-0.003	0.001	0.084^{***}
	(0.038)	(0.025)	(0.014)	(0.015)	(0.018)	(0.027)
Observations	398	162	1,333	451	885	336
R^2	0.052	0.284	0.108	0.267	0.143	0.556
Adjusted R^2	0.034	0.182	0.074	0.174	0.094	0.397
F Statistic	1.281	3.753^{***}	2.998^{***}	2.899^{***}	2.619^{***}	8.109^{***}
	(df = 11; 257)	(df = 11; 104)	(df = 37; 912)	(df = 37; 295)	(df = 37; 583)	(df = 37; 240)

Note: *p<0.1; **p<0.05; ***p<0.01
$^+$Individual time effects prevalent and displayed in the following table.
Source: Own Calculation

Table 42: Time Effects of the Fixed Effects Models on the Dependent Variable ROA with Reduced Subsets Based on Total Assets for Subsets of Sectors:
For the subset all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For the sectors energy, oil& gas and multis individual time effects are identified and displayed here. The robust covariance matrix is displayed in table 41.

	Dependent variable:			
	ROA – return on assets			
	(Energy)	(Electricity)	(Oil& Gas)	(Multis)
year 1982	-0.033^{***}	-0.006^{*}	-0.051^{***}	0.009^{***}
	(0.005)	(0.004)	(0.007)	(0.004)
year 1983	-0.008^{***}	0.011^{***}	-0.016^{***}	0.010^{***}
	(0.003)	(0.003)	(0.006)	(0.003)
year 1984	-0.010^{*}	-0.001	0.001	0.016^{*}
	(0.005)	(0.006)	(0.007)	(0.009)
year 1985	-0.014^{***}	0.003	-0.006	0.011
	(0.005)	(0.008)	(0.009)	(0.012)
year 1986	-0.010	-0.001	-0.004	0.007
	(0.007)	(0.009)	(0.009)	(0.014)
year 1987	-0.039^{***}	-0.006	-0.060^{***}	0.002
	(0.006)	(0.011)	(0.010)	(0.016)
year 1988	-0.028^{***}	-0.025^{**}	-0.012	-0.008
	(0.007)	(0.012)	(0.010)	(0.019)
year 1989	-0.038^{***}	-0.039^{***}	-0.025^{***}	-0.019
	(0.007)	(0.015)	(0.010)	(0.020)
year 1990	-0.051^{***}	-0.053^{***}	-0.036^{***}	-0.015
	(0.009)	(0.018)	(0.012)	(0.021)
year 1991	-0.048^{***}	-0.053^{***}	-0.033^{***}	-0.011
	(0.009)	(0.019)	(0.011)	(0.018)
year 1992	-0.049^{***}	-0.061^{***}	-0.022^{*}	-0.020
	(0.010)	(0.018)	(0.013)	(0.019)
year 1993	-0.054^{***}	-0.061^{***}	-0.036^{***}	-0.022
	(0.010)	(0.020)	(0.013)	(0.021)
year 1994	-0.064^{***}	-0.080^{***}	-0.039^{***}	-0.029
	(0.010)	(0.024)	(0.012)	(0.024)
year 1995	-0.061^{***}	-0.069^{***}	-0.033^{**}	-0.032
	(0.011)	(0.021)	(0.015)	(0.027)
year 1996	-0.058^{***}	-0.066^{***}	-0.026^{*}	-0.042
	(0.011)	(0.021)	(0.015)	(0.029)
year 1997	-0.068^{***}	-0.101^{***}	-0.032^{**}	-0.045
	(0.012)	(0.029)	(0.016)	(0.032)
year 1998	-0.077^{***}	-0.072^{***}	-0.061^{***}	-0.037
	(0.012)	(0.024)	(0.020)	(0.035)
year 1999	-0.068^{***}	-0.080^{***}	-0.032	-0.049
	(0.013)	(0.025)	(0.020)	(0.039)
year 2000	-0.048^{***}	-0.082^{***}	0.0003	-0.054
	(0.014)	(0.026)	(0.023)	(0.041)
year 2001	-0.065^{***}	-0.083^{***}	-0.020	-0.051
	(0.014)	(0.026)	(0.023)	(0.041)
year 2002	-0.082^{***}	-0.086^{***}	-0.048^{**}	-0.075^{*}
	(0.013)	(0.025)	(0.020)	(0.041)
year 2003	-0.065^{***}	-0.098^{***}	-0.013	-0.072
	(0.015)	(0.028)	(0.023)	(0.045)
year 2004	-0.065^{***}	-0.105^{***}	-0.009	-0.061
	(0.016)	(0.029)	(0.024)	(0.046)
year 2005	-0.053^{***}	-0.109^{***}	0.012	-0.070
	(0.017)	(0.029)	(0.027)	(0.049)
year 2006	-0.059^{***}	-0.106^{***}	0.007	-0.074
	(0.017)	(0.033)	(0.027)	(0.052)
year 2007	-0.065^{***}	-0.107^{***}	-0.001	-0.063
	(0.018)	(0.034)	(0.027)	(0.052)
Observations	1,333	451	885	336
R^2	0.108	0.267	0.143	0.556
Adjusted R^2	0.074	0.174	0.094	0.397
F Statistic	2.998^{***}	2.899^{***}	2.619^{***}	8.109^{***}
	(df = 37; 912)	(df = 37; 295)	(df = 37; 583)	(df = 37; 240)
Note:	*p<0.1; **p<0.05; ***p<0.01			
	Source: Own Calculation			

TABLE 43: Fixed Effects Models for the Subset of Sectors on the Dependent Variable Tobin's Q with Reduced Subsets Based on Total Assets:
For the subsets for each sector all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For the sectors energy, electricity and multis individual time effects are identified and displayed in the appendix in table 44.

	Dependent variable:					
	TQ					
	(Telecomm.)	(Transport)	(Energy^{+})	(Electricity^{+})	(Oil& Gas)	(Multis^{+})
ln.TotAss	-0.205^{**}	-0.083^{**}	-0.072^{***}	-0.079^{***}	-0.038	0.026
	(0.095)	(0.038)	(0.027)	(0.027)	(0.031)	(0.021)
ln.SalesGrowth	0.069^{**}	0.012	0.039^{**}	-0.005	0.053^{***}	0.004
	(0.030)	(0.009)	(0.015)	(0.006)	(0.017)	(0.005)
ln.DebtGrowth	-0.060^{***}	-0.008	-0.005	0.006	-0.005	-0.015^{***}
	(0.023)	(0.008)	(0.008)	(0.005)	(0.011)	(0.003)
ln.CapexGrowth	0.004	0.001	0.015^{**}	0.020^{***}	0.011	-0.002
	(0.020)	(0.012)	(0.006)	(0.007)	(0.008)	(0.003)
ln.BookToPrice	-0.713^{***}	-0.515^{***}	-0.581^{***}	-0.483^{***}	-0.645^{***}	-0.519^{***}
	(0.137)	(0.046)	(0.091)	(0.054)	(0.092)	(0.044)
lag(DiviPayou)	-0.001	-0.003^{***}	-0.001^{***}	-0.001^{***}	-0.002^{***}	-0.0001
	(0.002)	(0.001)	(0.001)	(0.0003)	(0.001)	(0.0004)
EarnDum	0.036	-0.146^{***}	0.105^{**}	0.050	0.109^{*}	-0.122^{**}
	(0.052)	(0.039)	(0.050)	(0.054)	(0.063)	(0.049)
DivDum	-0.003	0.096^{**}	-0.004	-0.005	-0.033	0.047^{*}
	(0.055)	(0.041)	(0.038)	(0.019)	(0.057)	(0.026)
ln.PopGrowth	0.165	-0.004	0.037^{**}	-0.0004	0.030	-0.058
	(0.120)	(0.018)	(0.016)	(0.015)	(0.021)	(0.042)
ln.GDPPCap	0.124	0.092	-0.261	-0.680^{***}	0.005	-1.334
	(0.952)	(0.204)	(0.360)	(0.253)	(0.284)	(1.544)
OECD-Aggr	-0.0001	-0.034	0.014	-0.079^{***}	-0.017	-0.009
	(0.071)	(0.029)	(0.030)	(0.024)	(0.044)	(0.056)
ln.PopGrowth	-0.598	-0.023	-0.294^{**}	-0.011	-0.242	1.450^{***}
	(0.374)	(0.151)	(0.140)	(0.109)	(0.178)	(0.437)
Observations	307	137	1,086	330	761	298
R^2	0.335	0.674	0.428	0.756	0.392	0.806
Adjusted R^2	0.199	0.413	0.286	0.477	0.263	0.573
F Statistic	7.647^{***}	14.445^{***}	14.271^{***}	16.992^{***}	27.434^{***}	23.176^{***}
	(df = 12; 182)	(df = 12; 84)	(df = 38; 725)	(df = 38; 208)	(df = 12; 510)	(df = 38; 212)

Note: *p<0.1; **p<0.05; ***p<0.01

$^{+}$Individual time effects prevalent and displayed in the following table.

Source: Own Calculation

TABLE 44: Time Effects of the Fixed Effects Models on the Dependent Variable Tobin's Q with Reduced Subsets Based on Total Assets for Subset of Sectors:
For the subset all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For all configurations individual time effects are identified and displayed here. The robust covariance matrix is displayed in table 43.

	Dependent variable:		
	TQ		
	(Energy)	(Electricity)	(Multis)
year 1982	0.068***	−0.042***	−0.053
	(0.021)	(0.014)	(0.045)
year 1983	0.039*	−0.067***	−0.075***
	(0.020)	(0.015)	(0.018)
year 1984	−0.026	0.001	0.134
	(0.038)	(0.052)	(0.132)
year 1985	−0.108**	−0.029	0.149
	(0.052)	(0.060)	(0.182)
year 1986	−0.057	−0.017	0.108
	(0.058)	(0.063)	(0.222)
year 1987	−0.032	−0.046	0.089
	(0.070)	(0.076)	(0.253)
year 1988	−0.083	−0.043	0.190
	(0.078)	(0.072)	(0.313)
year 1989	−0.040	−0.009	0.287
	(0.086)	(0.090)	(0.354)
year 1990	−0.092	−0.039	0.248
	(0.077)	(0.086)	(0.354)
year 1991	−0.087	−0.0002	0.318
	(0.103)	(0.103)	(0.330)
year 1992	−0.063	−0.007	0.287
	(0.103)	(0.101)	(0.362)
year 1993	−0.013	−0.011	0.267
	(0.099)	(0.093)	(0.384)
year 1994	−0.070	−0.034	0.240
	(0.101)	(0.103)	(0.429)
year 1995	0.030	−0.023	0.330
	(0.109)	(0.103)	(0.462)
year 1996	0.127	0.054	0.321
	(0.113)	(0.105)	(0.510)
year 1997	0.039	0.104	0.438
	(0.127)	(0.113)	(0.558)
year 1998	−0.007	0.064	0.522
	(0.131)	(0.111)	(0.602)
year 1999	0.011	0.020	0.396
	(0.139)	(0.123)	(0.660)
year 2000	0.010	0.167	0.542
	(0.135)	(0.123)	(0.704)
year 2001	−0.110	−0.056	0.434
	(0.137)	(0.128)	(0.717)
year 2002	−0.013	0.051	0.361
	(0.161)	(0.121)	(0.733)
year 2003	0.057	0.103	0.518
	(0.151)	(0.122)	(0.753)
year 2004	0.091	0.104	0.562
	(0.162)	(0.138)	(0.800)
year 2005	0.202	0.197	0.556
	(0.177)	(0.144)	(0.824)
year 2006	0.142	0.213	0.627
	(0.185)	(0.142)	(0.857)
year 2007	0.222	0.176	0.607
	(0.199)	(0.148)	(0.869)
Observations	1,086	330	298
R^2	0.428	0.756	0.806
Adjusted R^2	0.286	0.477	0.573
F Statistic	14.271***	16.992***	23.176***
	(df = 38; 725)	(df = 38; 208)	(df = 38; 212)
Note:	*p<0.1; **p<0.05; ***p<0.01		
	Source: Own Calculation		

A.0.5.4 Variance Inflation Factors

Table 45: Variance Inflation Factors for Sectors:
VIFS test for multicollinearity within the configurations. High multicollinearity is assumed for values over 5.0

ROA											
Teleco.	ln.TotAss 1.39	ln.SalesGrwth 1.47	ln.DebtGrwth 1.45	ln.CapxGrwth 1.48	DivPay 1.67	EarnDum 1.88	DivDum 1.37	PopGrwth 1.51	ln.GDPPCap 2.02	OECD-Aggr 1.99	HHI 1.84
Transp.	ln.TotAss 1.43	ln.SalesGrwth 1.30	ln.DebtGrwth 1.35	ln.CapxGrwth 1.40	DivPay 1.55	EarnDum 2.17	DivDum 1.86	PopGrwth 1.23	ln.GDPPCap 2.53	OECD-Aggr 1.64	HHI 1.57
Energy	ln.TotAss 1.40	ln.SalesGrwth 1.46	ln.DebtGrwth 1.44	ln.CapxGrwth 1.44	DivPay 1.55	EarnDum 1.71	DivDum 1.51	PopGrwth 1.25	ln.GDPPCap 2.10	OECD-Aggr 1.95	HHI 1.25
Elect.	ln.TotAss 1.25	ln.SalesGrwth 1.52	ln.DebtGrwth 1.54	ln.CapxGrwth 1.57	DivPay 1.43	EarnDum 1.59	DivDum 1.57	PopGrwth 1.48	ln.GDPPCap 2.01	OECD-Aggr 2.19	HHI 1.36
Oil&.Gas	ln.TotAss 1.52	ln.SalesGrwth 1.39	ln.DebtGrwth 1.35	ln.CapxGrwth 1.37	DivPay 1.55	EarnDum 1.95	DivDum 1.54	PopGrwth 1.17	ln.GDPPCap 2.26	OECD-Aggr 1.89	HHI 1.36
Multis	ln.TotAss 1.22	ln.SalesGrwth 1.25	ln.DebtGrwth 1.45	ln.CapxGrwth 1.36	DivPay 1.31	EarnDum 2.02	DivDum 1.99	PopGrwth 1.43	ln.GDPPCap 2.33	OECD-Aggr 1.85	HHI 2.33
TQ											
Teleco.	ln.TotAss 1.45	ln.SalesGrwth 1.49	ln.DebtGrwth 1.46	ln.CapxGrwth 1.44	ln.BookPrice 1.12	lag(DivPay) 1.67	EarnDum 1.88	DivDum 1.34	ln.PopGrwth 1.45	ln.GDPPCap 1.99	OECD-Aggr 2.08	HHI 1.79
Transp.	ln.TotAss 1.55	ln.SalesGrwth 1.36	ln.DebtGrwth 1.37	ln.CapxGrwth 1.46	ln.BookPrice 1.29	lag(DivPay) 1.76	EarnDum 1.87	DivDum 1.74	ln.PopGrwth 1.34	ln.GDPPCap 2.61	OECD-Aggr 1.46	HHI 1.44
Energy	ln.TotAss 1.41	ln.SalesGrwth 1.48	ln.DebtGrwth 1.43	ln.CapxGrwth 1.44	ln.BookPrice 1.23	lag(DivPay) 1.68	EarnDum 1.96	DivDum 1.66	ln.PopGrwth 1.17	ln.GDPPCap 2.26	OECD-Aggr 1.96	HHI 1.15
Elect.	ln.TotAss 1.33	ln.SalesGrwth 1.61	ln.DebtGrwth 1.60	ln.CapxGrwth 1.73	ln.BookPrice 1.29	lag(DivPay) 1.56	EarnDum 2.10	DivDum 1.89	ln.PopGrwth 1.32	ln.GDPPCap 2.30	OECD-Aggr 2.37	HHI 1.36
Oil&.Gas	ln.TotAss 1.47	ln.SalesGrwth 1.37	ln.DebtGrwth 1.35	ln.CapxGrwth 1.36	ln.BookPrice 1.23	lag(DivPay) 1.56	EarnDum 2.04	DivDum 1.67	ln.PopGrwth 1.16	ln.GDPPCap 2.41	OECD-Aggr 1.85	HHI 1.30
Multis	ln.TotAss 1.25	ln.SalesGrwth 1.25	ln.DebtGrwth 1.51	ln.CapxGrwth 1.41	ln.BookPrice 1.62	lag(DivPay) 1.17	EarnDum 2.48	DivDum 2.25	ln.PopGrwth 1.54	ln.GDPPCap 2.43	OECD-Aggr 2.08	HHI 1.89

Source: Own Calculation

TABLE 46: Variance Inflation Factors for Sectors with Reduced Subsets Based on Total Assets:
VIFS test for multicollinearity within the configurations. High multicollinearity is assumed for values over 5.0

ROA											
Teleco.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.40	1.49	1.43	1.49	1.75	1.89	1.39	1.55	1.99	2.06	1.92
Transp.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.38	1.31	1.30	1.37	1.60	2.22	1.86	1.32	2.52	1.63	1.54
Energy	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.37	1.47	1.44	1.43	1.58	1.69	1.50	1.24	2.13	1.96	1.25
Elect.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.30	1.53	1.55	1.57	1.43	1.57	1.56	1.52	2.04	2.18	1.43
Oil&Gas	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.45	1.39	1.35	1.34	1.56	1.92	1.51	1.16	2.34	1.93	1.35
Multis	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.16	1.25	1.47	1.37	1.31	2.11	2.08	1.33	2.39	1.86	2.30

TQ												
Teleco.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.47	1.52	1.44	1.44	1.17	1.78	1.86	1.37	1.53	1.98	2.17	1.90
Transp.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.40	1.38	1.30	1.41	1.31	1.85	1.86	1.73	1.45	2.59	1.46	1.39
Energy	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.37	1.49	1.43	1.43	1.25	1.70	1.96	1.65	1.17	2.30	1.98	1.14
Elect.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.31	1.61	1.60	1.73	1.27	1.58	2.14	1.89	1.32	2.32	2.35	1.37
Oil & Gas	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.39	1.37	1.34	1.33	1.24	1.57	2.02	1.65	1.17	2.54	1.91	1.28
Multis	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.22	1.25	1.48	1.42	1.62	1.15	2.79	2.44	1.48	2.47	2.10	1.89

Source: Own Calculation

A.0.5.5 Variances for F-Test or Welch-Test

Table 47: Tests for Variances of ROA for Sectors:
To examine whether different subsets show different means, it has to be tested whether the variances differ. In cases the variances differ the Welch-Test for different means has to be conducted, in cases with similar variance, the F-Test is conducted.

Variable	Data Sets	F	Num df	Denom df	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Ratio of Variance
ROA	telecommunication & transport	13452150.00	1954	894	2.2E-16	12012895.00	15028257.00	13452150.00
ROA	energy & transport	2411347.00	7521	894	2.2E-16	2181813.00	2654812.00	2411347.00
ROA	electricity & transport	200.68	2194	894	2.2E-16	179.53	223.73	200.68
ROA	oil and gas & transport	3404617.00	5326	894	2.2E-16	3074327.00	3756741.00	3404617.00
ROA	water & transport	4145.25	435	894	2.2E-16	3532.68	4886.48	4145.25
ROA	multi & transport	0.16	1272	894	2.2E-16	0.14	0.18	0.16
ROA	energy & telecommunication	0.18	7521	1954	2.2E-16	0.17	0.19	0.18
ROA	electricity & telecommunication	0.00	2194	1954	2.2E-16	0.00	0.00	0.00
ROA	oil and gas & telecommunication	0.25	5326	1954	2.2E-16	0.24	0.27	0.25
ROA	water & telecommunication	0.00	435	1954	2.2E-16	0.00	0.00	0.00
ROA	multi & telecommunication	0.00	1272	1954	2.2E-16	0.00	0.00	0.00
ROA	electricity & energy	0.00	2194	7521	2.2E-16	0.00	0.00	0.00
ROA	oil and gas & energy	1.41	5326	7521	2.2E-16	1.34	1.48	1.41
ROA	water & energy	0.00	435	7521	2.2E-16	0.00	0.00	0.00
ROA	multi & energy	0.00	1272	7521	2.2E-16	0.00	0.00	0.00
ROA	oil and gas & electricity	16965.78	5326	2194	2.2E-16	15805.31	18192.45	16965.78
ROA	water & electricity	20.66	435	2194	2.2E-16	17.92	23.98	20.66
ROA	multi & electricity	0.00	1272	2194	2.2E-16	0.00	0.00	0.00
ROA	water & oil and gas	0.00	435	5326	2.2E-16	0.00	0.00	0.00
ROA	multi & oil and gas	0.00	1272	5326	2.2E-16	0.00	0.00	0.00
ROA	water & multi	26127.58	435	1272	2.2E-16	22462.06	30571.08	26127.58

Source: Own Calculation

TABLE 48: Tests for Variances of Tobin's Q for Sectors:
To examine whether different subsets show different means, it has to be tested whether the variances differ. In cases the variances differ the Welch-Test for different means has to be conducted, in cases with similar variance, the F-Test is conducted.

Variable	Data Sets	F	Num df	Denom df	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Ratio of Variance
TQ	telecommunication & transport	10535.47	1981	911	2.2E-16	9417.58	11758.86	10535.47
TQ	energy & transport	839802.70	7642	911	2.2E-16	760579.20	923791.50	839802.70
TQ	electricity & transport	151186.60	2227	911	2.2E-16	135393.50	168395.60	151186.60
TQ	oil and gas & transport	1123174.00	5414	911	2.2E-16	1015184.00	1238238.00	1123174.00
TQ	water & transport	1.53	435	911	0.000000113	1.31	1.81	1.53
TQ	multi & transport	0.39	1272	911	2.2E-16	0.34	0.44	0.39
TQ	energy & telecommunication	79.71	7642	1981	2.2E-16	74.28	85.42	79.71
TQ	electricity & telecommunication	14.35	2227	1981	2.2E-16	13.17	15.63	14.35
TQ	oil and gas & telecommunication	106.61	5414	1981	2.2E-16	99.06	114.59	106.61
TQ	water & telecommunication	0.00	435	1981	2.2E-16	0.00	0.00	0.00
TQ	multi & telecommunication	0.00	1272	1981	2.2E-16	0.00	0.00	0.00
TQ	electricity & energy	0.18	2227	7642	2.2E-16	0.17	0.19	0.18
TQ	oil and gas & energy	1.34	5414	7642	2.2E-16	1.27	1.41	1.34
TQ	water & energy	0.00	435	7642	2.2E-16	0.00	0.00	0.00
TQ	multi & energy	0.00	1272	7642	2.2E-16	0.00	0.00	0.00
TQ	oil and gas & electricity	7.43	5414	2227	2.2E-16	6.92	7.96	7.43
TQ	water & electricity	0.00	435	2227	2.2E-16	0.00	0.00	0.00
TQ	multi & electricity	0.00	1272	2227	2.2E-16	0.00	0.00	0.00
TQ	water & oil and gas	0.00	435	5414	2.2E-16	0.00	0.00	0.00
TQ	multi & oil and gas	0.00	1272	5414	2.2E-16	0.00	0.00	0.00
TQ	water & multi	3.95	435	1272	2.2E-16	3.39	4.62	3.95

Source: Own Calculation

Table 49: Tests for Variances of ROA for Reduced Subsets of Sectors:
To examine whether different subsets show different means, it has to be tested whether the variances differ. In cases the variances differ the Welch-Test for different means has to be conducted, in cases with similar variance, the F-Test is conducted.

Variable	Data Sets	F	Num df	Denom df	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Ratio of Variance
ROA	telecommunication & transport	13514171.00	1859	853	2.2E-16	12034918.00	15137767.00	13514171.00
ROA	energy & transport	2376777.00	7293	853	2.2E-16	2145500.00	2622385.00	2376777.00
ROA	electricity & transport	198.74	2117	853	2.2E-16	177.36	222.10	198.74
ROA	oil and gas & transport	3350309.00	5173	853	2.2E-16	3018195.00	3704805.00	3350309.00
ROA	water & transport	4055.05	425	853	2.2E-16	3447.03	4792.34	4055.05
ROA	multi & transport	0.16	1215	853	2.2E-16	0.14	0.18	0.16
ROA	energy & telecommunication	0.18	7293	1859	2.2E-16	0.16	0.19	0.18
ROA	electricity & telecommunication	0.00	2117	1859	2.2E-16	0.00	0.00	0.00
ROA	oil and gas & telecommunication	0.25	5173	1859	2.2E-16	0.23	0.27	0.25
ROA	water & telecommunication	0.00	425	1859	2.2E-16	0.00	0.00	0.00
ROA	multi & telecommunication	0.00	1215	1859	2.2E-16	0.00	0.00	0.00
ROA	electricity & energy	0.00	2117	7293	2.2E-16	0.00	0.00	0.00
ROA	oil and gas & energy	1.41	5173	7293	2.2E-16	1.34	1.48	1.41
ROA	water & energy	0.00	425	7293	2.2E-16	0.00	0.00	0.00
ROA	multi & energy	0.00	1215	7293	2.2E-16	0.00	0.00	0.00
ROA	oil and gas & electricity	16857.69	5173	2117	2.2E-16	15685.45	18097.86	16857.69
ROA	water & electricity	20.40	425	2117	2.2E-16	17.67	23.73	20.40
ROA	multi & electricity	0.00	1215	2117	2.2E-16	0.00	0.00	0.00
ROA	water & oil and gas	0.00	425	5173	2.2E-16	0.00	0.00	0.00
ROA	multi & oil and gas	0.00	1215	5173	2.2E-16	0.00	0.00	0.00
ROA	water & multi	26086.79	425	1215	2.2E-16	22377.13	30593.43	26086.79

Source: Own Calculation

TABLE 50: Tests for Variances of Tobin's Q for Reduced Subsets of Sectors:
To examine whether different subsets show different means, it has to be tested whether the variances differ. In cases the variances differ the Welch-Test for different means has to be conducted, in cases with similar variance, the F-Test is conducted.

Variable	Data Sets	F	Num df	Denom df	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Ratio of Variance
TQ	telecommunication & transport	10586.19	1886	867	2.2E-16	9436.11	11847.65	10586.19
TQ	energy & transport	828229.00	7414	867	2.2E-16	748270.60	913100.40	828229.00
TQ	electricity & transport	149830.40	2150	867	2.2E-16	133832.90	167290.70	149830.40
TQ	oil and gas & transport	1105901.00	5261	867	2.2E-16	997138.10	1221932.70	1105901.00
TQ	water & transport	1.50	425	867	8.511E-07	1.27	1.77	1.50
TQ	multi & transport	0.38	1215	867	2.2E-16	0.33	0.43	0.38
TQ	energy & telecommunication	78.24	7414	1886	2.2E-16	72.78	83.97	78.24
TQ	electricity & telecommunication	14.15	2150	1886	2.2E-16	12.97	15.45	14.15
TQ	oil and gas & telecommunication	104.47	5261	1886	2.2E-16	96.91	112.46	104.47
TQ	water & telecommunication	0.00	425	1886	2.2E-16	0.00	0.00	0.00
TQ	multi & telecommunication	0.00	1215	1886	2.2E-16	0.00	0.00	0.00
TQ	electricity & energy	0.18	2150	7414	2.2E-16	0.17	0.19	0.18
TQ	oil and gas & energy	1.34	5261	7414	2.2E-16	1.27	1.40	1.34
TQ	water & energy	0.00	425	7414	2.2E-16	0.00	0.00	0.00
TQ	multi & energy	0.00	1215	7414	2.2E-16	0.00	0.00	0.00
TQ	oil and gas & electricity	7.38	5261	2150	2.2E-16	6.87	7.92	7.38
TQ	water & electricity	0.00	425	2150	2.2E-16	0.00	0.00	0.00
TQ	multi & electricity	0.00	1215	2150	2.2E-16	0.00	0.00	0.00
TQ	water & oil and gas	0.00	425	5261	2.2E-16	0.00	0.00	0.00
TQ	multi & oil and gas	0.00	1215	5261	2.2E-16	0.00	0.00	0.00
TQ	water & multi	3.97	425	1215	2.2E-16	3.40	4.65	3.97

Source: Own Calculation

A.0.5.6 Means for Subsets

Table 51: Tests for Means of ROA of Reduced Subsets Based on Total Assets for Sectors :
Here the robustness of the tests of different means is tested. For each sector a reduced subset based on high total assets is created and tests. The means do not differ, comparably to the full subsets.

Variable Variable	Data Sets	T	DF	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Mean Set 1	Mean Set 2
ROA	telecommunication & transport	-1.01	1859.00	0.31	-25.10	8.07	-8.46	0.05
ROA	energy & transport	-1.59	7293.05	0.11	-6.35	0.67	-2.79	0.05
ROA	electricity & transport	-3.54	2169.33	0.00	-0.17	-0.05	-0.06	0.05
ROA	oil and gas & transport	-1.57	5173.02	0.12	-8.91	0.99	-3.91	0.05
ROA	water & transport	-0.95	425.11	0.34	-0.89	0.31	-0.24	0.05
ROA	multi & transport	7.51	1040.70	0.00	0.02	0.03	0.08	0.05
ROA	energy & telecommunication	0.66	2028.45	0.51	-11.28	22.63	-2.79	-8.46
ROA	electricity & telecommunication	0.99	1859.05	0.32	-8.18	24.99	-0.06	-8.46
ROA	oil and gas & telecommunication	0.52	2198.84	0.61	-12.75	21.86	-3.91	-8.46
ROA	water & telecommunication	0.97	1863.86	0.33	-8.37	24.82	-0.24	-8.46
ROA	multi & telecommunication	1.01	1859.00	0.31	-8.04	25.13	0.08	-8.46
ROA	electricity & energy	1.53	7297.20	0.13	-0.78	6.24	-0.06	-2.79
ROA	oil and gas & energy	-0.36	9909.42	0.72	-7.19	4.95	-3.91	-2.79
ROA	water & energy	1.40	7613.82	0.16	-1.01	6.11	-0.24	-2.79
ROA	multi & energy	1.60	7293.01	0.11	-0.64	6.38	0.08	-2.79
ROA	oil and gas & electricity	-1.53	5174.50	0.13	-8.80	1.10	-3.91	-0.06
ROA	water & electricity	-0.60	433.41	0.55	-0.79	0.42	-0.24	-0.06
ROA	multi & electricity	4.45	2122.77	0.00	0.08	0.19	0.08	-0.06
ROA	water & oil and gas	1.44	5312.24	0.15	-1.32	8.65	-0.24	-3.91
ROA	multi & oil and gas	1.58	5173.00	0.11	-0.96	8.94	0.08	-3.91
ROA	water & multi	-1.04	425.01	0.30	-0.92	0.28	-0.24	0.08

Source: Own Calculation

TABLE 52: Tests for Means of Tobin's Q of Reduced Subsets Based on Total Assets for Sectors :
Here the robustness of the tests of different means is tested. For each sector a reduced subset based on high total assets is created and tests. The means do not differ, comparably to the full subsets.

Variable Variable	Data Sets	T	DF	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Mean Set 1	Mean Set 2
TQ	telecommunication & transport	2.89	1886.78	0.00	1.11	5.80	4.67	1.22
TQ	energy & transport	2.16	7414.15	0.03	1.07	22.01	12.75	1.22
TQ	electricity & transport	1.75	2150.07	0.08	-0.90	15.64	8.59	1.22
TQ	oil and gas & transport	1.81	5261.06	0.07	-1.12	27.60	14.46	1.22
TQ	water & transport	1.77	711.84	0.08	-0.01	0.13	NV	NV
TQ	multi & transport	-3.65	1328.11	0.00	-0.11	-0.03	1.15	1.22
TQ	energy & telecommunication	1.48	8097.16	0.14	-2.65	18.81	12.75	4.67
TQ	electricity & telecommunication	0.89	2491.84	0.37	-4.68	12.51	8.59	4.67
TQ	oil and gas & telecommunication	1.32	5534.62	0.19	-4.77	24.34	14.46	4.67
TQ	water & telecommunication	-2.84	1888.36	0.00	-5.74	-1.05	1.28	4.67
TQ	multi & telecommunication	-2.95	1886.21	0.00	-5.87	-1.18	1.15	4.67
TQ	electricity & energy	-0.61	8348.44	0.54	-17.51	9.18	8.59	12.75
TQ	oil and gas & energy	0.19	10278.86	0.85	-16.07	19.48	14.46	12.75
TQ	water & energy	-2.15	7414.47	0.03	-21.94	-1.00	1.28	12.75
TQ	multi & energy	-2.17	7414.04	0.03	-22.08	-1.14	1.15	12.75
TQ	oil and gas & electricity	0.69	7350.47	0.49	-10.70	22.44	14.46	8.59
TQ	water & electricity	-1.73	2150.22	0.08	-15.58	0.96	1.28	8.59
TQ	multi & electricity	-1.76	2150.02	0.08	-15.71	0.83	1.15	8.59
TQ	water & oil and gas	-1.80	5261.18	0.07	-27.54	1.18	1.28	14.46
TQ	multi & oil and gas	-1.82	5261.02	0.07	-27.68	1.05	1.15	14.46
TQ	water & multi	4.21	501.99	0.00	0.07	0.19	1.28	1.15

Source: Own Calculation

A.0.6 Additional Empirical Data for Subsets of Different Degrees of Vertical Integration

A.0.6.1 Empirical Tests

Table 53: Tests for Fixed Effects Models on ROA and Subsets of Vertical Integration:
For each degree of vertical integration on the dependent variable ROA tests are executed to determine whether the panel data can be estimated versus a simple ordinary least square model or whether fixed effects and random effects are the better fit. Additionally the test results for heteroskedasticity and serial correlation are displayed. For the decreased subsets to conduct the robustness tests, all tests are equally conducted and displayed.

	Firms owning nodes and edges (both)	Firms additionally offering services (service)	Firms completely vertically integrated (vertical integration
Subsamples based on the total set			
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.4891	0.07413	1.49E-07
RE versus FE: Hausmann test: if p<0.05 then FE.	< 2.2e-16	5.04E-14	< 2.2e-16
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	0.001769	0.0004936	2.31E-07
Sub samples - exclusions per subsample based on high total assets			
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.5957	0.1842	1.81E-05
RE versus FE: Hausmann test: if p<0.05 then FE.	< 2.2e-16	< 2.2e-16	8.21E-10
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	0.0004539	0.0001545	0.004951

Source: Own Calculation

TABLE 54: Tests for Fixed Effects Models on Tobin's Q and Subsets of Vertical Integration:
For each degree of vertical integration on the dependent variable Tobin's Q tests are executed to determine whether the panel data can be estimated versus a simple ordinary least square model or whether fixed effects and random effects are the better fit. Additionally the test results for heteroskedasticity and serial correlation are displayed. For the decreased subsets to conduct the robustness tests, all tests are equally conducted and displayed.

	Firms owning nodes and edges (both)	Firms additionally offering services (service)	Firms completely vertically integrated(vertical integration)
Subsamples based on the total set			
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.8757	0.1057	7.84E-07
RE versus FE: Hausmann test: if p<0.05 then FE.	0.0001491	5.25E-05	0.03771
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	1.23E-08	0.0002333	9.99E-08
Sub samples - exclusions per subsample based on high total assets			
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.9547	0.2953	2.46E-05
RE versus FE: Hausmann test: if p<0.05 then FE.	< 2.2e-16	< 2.2e-16	0.1226
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	7.54E-08	0.2365	4.13E-09

Source: Own Calculation

A.0.6.2 Individual Fixed Time Effects

TABLE 55: Individual Time Effects of Subsets of Vertical Integration Regressed in a Fixed Effects Models on ROA and Tobin's Q:
The models are fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For the subset "vertical integration" individual time effects are identified and displayed for the full sample and the reduceds subsample. The main robust covariance matrix is displayed in table 16 for the full sample and table 56 for the subsample on ROA, in table 17 for the full sample and table 57 for the reduced subsample on TQ.

	Dependent variable:			
	ROA		Tobin's Q	
	Vertical Intergation			
	(Full Sample)	(Subsample)	(Full Sample)	(Subsample)
year 1982	0.001	0.001	−0.024	−0.038
	(0.002)	(0.002)	(0.020)	(0.033)
year 1983	0.004*	0.005**	−0.043**	−0.075**
	(0.002)	(0.002)	(0.021)	(0.031)
year 1984	0.001	0.001	0.053	0.013
	(0.003)	(0.004)	(0.033)	(0.058)
year 1985	0.008**	0.010**	0.016	−0.027
	(0.004)	(0.004)	(0.035)	(0.060)
year 1986	0.007	0.006	−0.045	−0.082
	(0.005)	(0.006)	(0.043)	(0.053)
year 1987	−0.009*	−0.007	−0.067	−0.092
	(0.005)	(0.007)	(0.044)	(0.062)
year 1988	−0.018***	−0.017**	0.020	−0.067
	(0.006)	(0.007)	(0.049)	(0.085)
year 1989	−0.029***	−0.027***	0.055	−0.003
	(0.007)	(0.008)	(0.055)	(0.088)
year 1990	−0.029***	−0.028***	0.008	−0.072
	(0.008)	(0.009)	(0.060)	(0.096)
year 1991	−0.025***	−0.025***	0.005	−0.064
	(0.007)	(0.009)	(0.061)	(0.086)
year 1992	−0.028***	−0.028***	0.015	−0.069
	(0.007)	(0.009)	(0.067)	(0.091)
year 1993	−0.030***	−0.030***	0.033	−0.034
	(0.008)	(0.010)	(0.065)	(0.098)
year 1994	−0.042***	−0.041***	−0.080	−0.157
	(0.009)	(0.011)	(0.076)	(0.108)
year 1995	−0.036***	−0.035***	0.117	0.024
	(0.008)	(0.011)	(0.083)	(0.119)
year 1996	−0.036***	−0.036***	0.114	0.025
	(0.009)	(0.011)	(0.086)	(0.126)
year 1997	−0.044***	−0.043***	0.146	0.030
	(0.011)	(0.013)	(0.093)	(0.135)
year 1998	−0.031***	−0.032***	0.223**	0.120
	(0.009)	(0.012)	(0.092)	(0.154)
year 1999	−0.039***	−0.038***	0.078	−0.048
	(0.011)	(0.013)	(0.112)	(0.170)
year 2000	−0.037***	−0.036**	0.113	0.003
	(0.011)	(0.014)	(0.127)	(0.191)
year 2001	−0.045***	−0.043***	0.068	−0.072
	(0.011)	(0.014)	(0.125)	(0.188)
year 2002	−0.053***	−0.048***	0.099	−0.062
	(0.011)	(0.015)	(0.129)	(0.192)
year 2003	−0.053***	−0.051***	0.227	0.046
	(0.012)	(0.016)	(0.142)	(0.187)
year 2004	−0.046***	−0.046***	0.244*	0.104
	(0.012)	(0.016)	(0.146)	(0.215)
year 2005	−0.045***	−0.045***	0.370**	0.266
	(0.012)	(0.016)	(0.174)	(0.223)
year 2006	−0.039***	−0.041**	0.201	0.046
	(0.013)	(0.017)	(0.168)	(0.196)
year 2007	−0.040***	−0.042**	0.324**	0.122
	(0.014)	(0.018)	(0.158)	(0.230)
Constant				6.199
				(4.939)
Observations	1,190	1,119	996	935
R^2	0.195	0.182	0.581	0.666
Adjusted R^2	0.148	0.136	0.438	0.638
F Statistic	5.935*** (	5.030***	27.390***	47.008***
	(df = 37; 905)	(df = 37; 839)	(df = 38; 750)	(df = 38; 896)
Note:				*p<0.1; **p<0.05; ***p<0.01 textitSource: Own Calculation

A.0.6.3 Results of Decreased Subsets for Robustness Tests

Table 56: Fixed Effects Models for Subsets of Vertical Integration on the Dependent Variable ROA with a Reduced Subsets Based on Total Assets: For the subsets for each degree of vertical integration all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. The individual time effects for the subsets vertical integration are displayed in table 55.

	Dependent variable		
	ROA		
	(Both)	(Service)	(Vertical Integration)
ln.TotAss	0.004	0.007*	−0.012***
	(0.005)	(0.004)	(0.003)
ln.SalesGrowth	0.007**	−0.004	0.003***
	(0.003)	(0.002)	(0.001)
ln.DebtGrowth	−0.003*	−0.003*	−0.001
	(0.002)	(0.002)	(0.001)
ln.CapexGrowth	0.001	0.001	−0.002**
	(0.002)	(0.001)	(0.001)
DiviPayou	−0.0004*	−0.0002	−0.0003***
	(0.0003)	(0.0002)	(0.0001)
EarnDum	0.013	0.007	0.006
	(0.010)	(0.006)	(0.005)
DivDum	−0.005	0.009	0.006*
	(0.011)	(0.006)	(0.003)
PopGrowth	−0.001	0.018**	0.019**
	(0.014)	(0.008)	(0.008)
ln.GDPPCap	0.039	−0.107***	0.040
	(0.082)	(0.031)	(0.033)
OECD-Aggr	0.019***	−0.009	−0.013***
	(0.006)	(0.006)	(0.003)
ln.PopGrowth	−0.034	0.020	−0.023**
	(0.028)	(0.027)	(0.010)
Observations	487	734	1,119
R^2	0.045	0.034	0.182
Adjusted R^2	0.026	0.024	0.136
F Statistic	1.217	1.667*	5.030***
	(df = 11; 284)	(df = 11; 519)	(df = 37; 839)
Note:			*p<0.1; **p<0.05; ***p<0.01
			Source: Own Calculation

Table 57: Fixed Effects Models for Subsets of Vertical Integration on the Dependent Variable Tobin's Q with Reduced Subsets Based on Total Assets: For the subsets for each degree of vertical integration all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. The individual time effects for the subsets vertical integration and services are displayed in table 55.

	Dependent variable		
	Tobin's Q		
	(Both)	(Service)	(Vertical Integration) (Random Effects+)
ln.TotAss	-0.047^{*}	-0.073^{**}	-0.041^{*}
	(0.028)	(0.034)	(0.021)
ln.SalesGrowth	0.074^{***}	0.020	0.019^{**}
	(0.023)	(0.015)	(0.008)
ln.DebtGrowth	−0.007	−0.011	-0.020^{***}
	(0.016)	(0.011)	(0.007)
ln.CapexGrowth	0.022^{**}	0.014	−0.006
	(0.010)	(0.009)	(0.006)
ln.BookToPrice	-0.636^{***}	-0.650^{***}	-0.626^{***}
	(0.130)	(0.092)	(0.088)
lag(DiviPayou)	−0.001	-0.001^{**}	-0.001^{*}
	(0.001)	(0.001)	(0.001)
EarnDum	0.204^{**}	0.013	−0.015
	(0.096)	(0.051)	(0.040)
DivDum	−0.090	−0.018	−0.0004
	(0.085)	(0.027)	(0.028)
ln.PopGrowth	0.061^{**}	−0.010	0.042
	(0.027)	(0.019)	(0.036)
ln.GDPPCap	0.424	−0.100	−0.466
	(0.432)	(0.212)	(0.471)
OECD-Aggr	0.048	−0.035	0.001
	(0.071)	(0.039)	(0.026)
ln.PopGrowth	−0.584	-0.446^{*}	0.016
	(0.452)	(0.235)	(0.141)
Constant			6.199
			(4.939)
Observations	403	606	935
R^2	0.379	0.289	0.666
Adjusted R^2	0.213	0.198	0.638
F Statistic	11.543^{***}	14.042^{***}	47.008^{***}
	(df = 12; 227)	(df = 12; 415)	(df = 38; 896)

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

+Individual time effects prevalent and displayed in the following table.

Source: Own Calculation

A.0.6.4 Variance Inflation Factors

TABLE 58: Variance Inflation Factors for Subsets of Vertical Integration:
VIFS test for multicollinearity within the configurations. High multicollinearity is assumed for values over 5.0

Vertical integration full set												
ROA												
Both	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.30	1.35	1.32	1.24	1.58	1.67	1.47	1.22	2.36	1.58	1.87	
Service	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.21	1.49	1.44	1.43	1.53	1.79	1.46	1.26	2.27	1.98	1.59	
VI	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.08	1.28	1.34	1.35	1.23	1.70	1.62	1.37	2.12	1.95	1.32	
Tobin's Q												
Both	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.33	1.29	1.28	1.20	1.12	1.65	1.72	1.52	1.29	1.98	1.51	1.73
Service	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.31	1.46	1.36	1.37	1.19	1.48	2.02	1.51	1.24	1.73	1.85	1.61
VI	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.26	1.31	1.43	1.51	1.25	1.41	1.94	1.78	1.28	1.41	1.41	1.15
Vertical integration in reduced subsets based on total assets												
ROA												
Both	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.30	1.36	1.30	1.24	1.58	1.65	1.46	1.27	2.33	1.61	1.92	
Service	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.21	1.50	1.44	1.43	1.55	1.77	1.45	1.25	2.31	2.03	1.58	
VI	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.07	1.27	1.33	1.33	1.25	1.70	1.64	1.37	2.12	2.00	1.31	
Tobin's Q												
Both	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.33	1.30	1.26	1.20	1.13	1.62	1.70	1.51	1.33	1.94	1.52	1.75
Service	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.30	1.47	1.36	1.37	1.20	1.49	2.02	1.49	1.25	1.74	1.90	1.60
VI	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapexGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECDDetail	HHI
	1.21	1.31	1.41	1.50	1.25	1.46	2.00	1.83	1.27	1.44	1.43	1.12

Source: Own Calculation

A.0.6.5 Variances for F-Test or Welch-Test

Table 59: Tests for Variances for the Subsets of Vertical Integration:
To examine whether different subsets show different means, it has to be tested whether the variances differ. In cases the variances differ the Welch-Test for different means has to be conducted, in cases with similar variance, the F-Test is conducted.

Variable	Data Sets	F	Num df	Denom df	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Ratio of Variance
ROA	both & vert. integr.	31865.97	3642	4897	2.2E-16	29994.59	33863.38	31865.97
ROA	service & vert. integr.	25.73	3539	4897	2.2E-16	24.21	27.36	25.73
ROA	service & both	0.00	3539	3642	2.2E-16	0.00	0.00	0.00
TQ	both & vert. integr.	4941.53	3731	4926	2.2E-16	4653.58	5248.63	4941.53
TQ	service & vert. integr.	455.45	3586	4926	2.2E-16	428.62	484.09	455.45
TQ	service & both	0.09	3586	3731	2.2E-16	0.09	0.10	0.09
Subsets of vertical integration based on total assets								
Variable	Data Sets	F	Num df	Denom df	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Ratio of Variance
ROA	both & vert. integr.	31724.81	3497	4681	2.2E-16	29822.91	33757.51	31724.81
ROA	service & vert. integr.	25.20	3455	4681	2.2E-16	23.68	26.82	25.20
ROA	service & both	0.00	3455	3497	2.2E-16	0.00	0.00	0.00
TQ	both & vert. integr.	4916.82	3585	4709	2.2E-16	4624.39	5229.10	4916.82
TQ	service & vert. integr.	445.87	3502	4709	2.2E-16	419.18	474.39	445.87
TQ	service & both	0.09	3502	3585	2.2E-16	0.08	0.10	0.09

Source: Own Calculation

A.0.6.6 Means for Subsets

TABLE 60: Tests for Means of Reduced Subsets Based on Total Assets for Subsets of Vertical Integration: Here the robustness of the tests of different means is tested. For each subset of vertical integration a reduced subset based on high total assets is created and tests. The means do not differ, comparably to the full subsets.

Variable	Data Sets	T	DF	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Mean Set 1	Mean Set 2
ROA	both & vert. integr.	-1.74	3497.17	0.08	-21.62	1.29	-10.12	0.04
ROA	service & vert. integr.	-1.58	3658.06	0.12	-0.59	0.06	-0.23	0.04
ROA	service & both	1.69	3502.62	0.09	-1.56	21.36	0.00	-0.23
TQ	both & vert. integr.	1.52	3586.11	0.13	-4.63	36.94	17.58	1.42
TQ	service & vert. integr.	2.79	3513.69	0.01	2.68	15.35	10.44	1.42
TQ	service & both	-0.64	4244.05	0.52	-28.86	14.59	0.00	10.44

Source: Own Calculation

A.0.7 Additional Empirical Data for Subsets for Different Types of Networks

A.0.7.1 Empirical Tests

TABLE 61: Tests for Fixed Effects Modeland Different Types for Networks: For each sector on the dependent variables ROA and Tobin's Q tests are executed to determine whether the panel data can be estimated versus a simple ordinary least square model or whether fixed effects and random effects are the better fit. Additionally the test results for heteroskedasticity and serial correlation are displayed. For the decreased subsets to conduct the robustness tests, all tests are equally conducted and displayed.

	ROA		TQ	
Subsamples based on the total set	firms active in directed networks	firms active in undirected networks	firms active in directed networks	firms active in undirected networks
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	1.62E-06	0.3885	0.008123	0.04826
RE versus FE: Hausmann test: if p<0.05 then FE.	< 2.2e-16	0.0002874	< 2.2e-16	0.000637
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	0.0265	0.08487	6.42E-09	0.0001347
Sub samples - exclusions per subsample based on high total assets				
Random effects (RE) versus ordinary least squares (OLS): Lagrange Multiplier Test (Breuch -Pagan)): if p<0.05 then RE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed effects (FE) versus OLS: F-Test for individual effects: if p<0.05 then time FE.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Time effects: Lagrange-Multiplier: if p<0.05 then time effects.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Fixed time effects: F-test for individual time effects: if p<0.05 then individual time fixed effects.	0.000578	0.5036	0.02001	0.2052
RE versus FE: Hausmann test: if p<0.05 then FE.	< 2.2e-16	0.701	< 2.2e-16	0.0005385
Heteroskedasticity: Breusch-Pagan Test: if p<0.05 then heteroskedasticity.	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16
Serial correlation: Breusch-Godfrey/Wooldridge test: if p<0.05 than serial correlation.	3.99E-05	0.06955	3.28E-09	0.01254

Source: Own Calculation

A.0.7.2 Individual Time Fixed Effects

TABLE 62: Fixed Effects Models for all Dependent Variables for Different Types of Networks:
Fixed Effects Models, using Arellano robust covariance matrix estimation. The total set of all firms is divided into two sets, one only including firms active in directed networks(water, oil & gas, electricity, broadcasting) , one including firms active in undirected networks (most telecommunication and transport). The main robust covariance matrix is displayed in chapter 5, table 19

	Dependent variable:		
	ROA	TQ	
	(Directed)	(Directed)	(Undirected)
year 1982	−0.029***	0.074***	
	(0.004)	(0.022)	
year 1983	−0.007***	0.031	0.089
	(0.002)	(0.019)	(0.153)
year 1984	−0.004	−0.015	−0.379**
	(0.005)	(0.032)	(0.155)
year 1985	−0.007	−0.046	−0.077
	(0.006)	(0.039)	(0.147)
year 1986	−0.002	−0.057	−0.046
	(0.006)	(0.040)	(0.127)
year 1987	−0.028***	−0.048	−0.062
	(0.005)	(0.049)	(0.157)
year 1988	−0.019***	−0.060	0.013
	(0.006)	(0.061)	(0.233)
year 1989	−0.028***	0.001	−0.095
	(0.007)	(0.065)	(0.295)
year 1990	−0.037***	−0.052	−0.218
	(0.008)	(0.059)	(0.304)
year 1991	−0.037***	−0.039	−0.138
	(0.008)	(0.067)	(0.293)
year 1992	−0.035***	−0.010	−0.127
	(0.008)	(0.069)	(0.334)
year 1993	−0.039***	0.037	−0.190
	(0.009)	(0.068)	(0.382)
year 1994	−0.051***	−0.042	−0.346
	(0.008)	(0.077)	(0.422)
year 1995	−0.048***	0.074	0.041
	(0.009)	(0.081)	(0.451)
year 1996	−0.047***	0.149*	−0.032
	(0.009)	(0.087)	(0.458)
year 1997	−0.048***	0.095	−0.388
	(0.009)	(0.095)	(0.503)
year 1998	−0.053***	0.077	0.159
	(0.011)	(0.102)	(0.511)
year 1999	−0.052***	0.069	0.246
	(0.011)	(0.105)	(0.509)
year 2000	−0.029**	0.060	−0.318
	(0.012)	(0.113)	(0.598)
year 2001	−0.046***	−0.031	−0.240
	(0.012)	(0.116)	(0.653)
year 2002	−0.062***	0.016	−0.040
	(0.012)	(0.126)	(0.571)
year 2003	−0.048***	0.108	0.022
	(0.014)	(0.125)	(0.583)
year 2004	−0.045***	0.147	0.110
	(0.013)	(0.135)	(0.607)
year 2005	−0.030**	0.263*	0.235
	(0.015)	(0.142)	(0.650)
year 2006	−0.032**	0.199	0.019
	(0.014)	(0.145)	(0.670)
year 2007	−0.039**	0.264*	0.134
	(0.015)	(0.157)	(0.652)
Observations	1,573	1,305	441
R^2	0.114	0.438	0.499
Adjusted R^2	0.080	0.303	0.294
F Statistic	3.857***	18.502***	7.003***
	(df = 37; 1107)	(df = 38; 903)	(df = 37; 260)
Note:			*p<0.1; **p<0.05; ***p<0.01
			Source: Own Calculation

A.0.7.3 Results of Decreased Subsets for Robustness Tests

TABLE 63: Fixed Effects Models for Different Types of Networks with Reduced Subsets Based on Total Assets:
For the subsets for each sector all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For firms active in undirected networks individual time effects are identified and displayed in the appendix in table 64.

	Dependent variable:			
	ROA		TQ	
	(Undirected)	(Directed)	(Undirected)	(Directed)
ln.TotAss	0.003	−0.007	−0.076***	−0.150**
	(0.003)	(0.006)	(0.026)	(0.068)
ln.SalesGrowth	0.004***	−0.006**	0.037***	0.026*
	(0.001)	(0.003)	(0.013)	(0.015)
ln.DebtGrowth	−0.002**	−0.004	−0.010	−0.040**
	(0.001)	(0.002)	(0.008)	(0.017)
ln.CapexGrowth	−0.001	0.003	0.012*	−0.003
	(0.001)	(0.002)	(0.007)	(0.017)
DiviPayou	−0.0004***	0.0002		
	(0.0001)	(0.0002)		
ln.BookToPrice			−0.565***	−0.696***
			(0.077)	(0.117)
lag(DiviPayou)			−0.002***	−0.002
			(0.0005)	(0.001)
EarnDum	0.002	0.019**	0.094**	−0.015
	(0.005)	(0.007)	(0.046)	(0.054)
DivDum	0.004	0.001	−0.018	−0.027
	(0.005)	(0.009)	(0.030)	(0.050)
PopGrowth	0.016***	0.024*		
	(0.004)	(0.014)		
ln.PopGrowth			0.040***	0.022
			(0.015)	(0.029)
ln.GDPPCap	−0.005	0.053**	−0.288	0.148
	(0.036)	(0.025)	(0.383)	(0.503)
OECD-Aggr	−0.002	0.005	0.012	−0.020
	(0.004)	(0.003)	(0.027)	(0.039)
ln.PopGrowth	−0.003	−0.021	−0.289**	−0.321
	(0.012)	(0.025)	(0.115)	(0.225)
Observations	1,498	514	1,232	417
R^2	0.097	0.044	0.423	0.337
Adjusted R^2	0.067	0.030	0.287	0.213
F Statistic	3.009***	1.446	16.152***	11.182***
	(df = 37; 1040)	(df = 11; 343)	(df = 38; 837)	(df = 12; 264)

Note: *p<0.1; **p<0.05; ***p<0.01
Source: Own Calculation

Table 64: Fixed Effects Models for Different Types of Networks with Reduced Subsets Based on Total Assets:
For the subsets for each sector all firms with high total assets are excluded. The model is a fixed effects model, adjusted by the Arellano robust covariance matrix to account for serial correlation and heteroskedasticity. For firms active in undirected networks individual time effects are identified and displayed in the appendix in table 63.

	Dependent variable:	
	ROA (Undirected)	TQ (Undirected)
year 1982	−0.031***	0.059***
	(0.004)	(0.021)
year 1983	−0.007***	0.022
	(0.003)	(0.019)
year 1984	−0.004	−0.029
	(0.005)	(0.034)
year 1985	−0.009	−0.067
	(0.006)	(0.042)
year 1986	−0.006	−0.073*
	(0.006)	(0.044)
year 1987	−0.030***	−0.063
	(0.006)	(0.051)
year 1988	−0.018***	−0.069
	(0.007)	(0.066)
year 1989	−0.026***	−0.006
	(0.007)	(0.072)
year 1990	−0.038***	−0.067
	(0.009)	(0.065)
year 1991	−0.033***	−0.050
	(0.009)	(0.076)
year 1992	−0.036***	−0.029
	(0.009)	(0.076)
year 1993	−0.040***	0.018
	(0.010)	(0.074)
year 1994	−0.051***	−0.048
	(0.009)	(0.083)
year 1995	−0.045***	0.053
	(0.010)	(0.090)
year 1996	−0.045***	0.139
	(0.010)	(0.095)
year 1997	−0.045***	0.072
	(0.010)	(0.100)
year 1998	−0.054***	0.062
	(0.012)	(0.111)
year 1999	−0.048***	0.047
	(0.012)	(0.117)
year 2000	−0.029**	0.049
	(0.013)	(0.124)
year 2001	−0.045***	−0.051
	(0.013)	(0.127)
year 2002	−0.058***	−0.009
	(0.013)	(0.144)
year 2003	−0.045***	0.081
	(0.014)	(0.139)
year 2004	−0.045***	0.128
	(0.014)	(0.147)
year 2005	−0.031*	0.253*
	(0.016)	(0.148)
year 2006	−0.036**	0.183
	(0.016)	(0.159)
year 2007	−0.040**	0.253
	(0.016)	(0.175)
Observations	1,498	1,232
R^2	0.097	0.423
Adjusted R^2	0.067	0.287
F Statistic	3.009***	16.152***
	(df = 37; 1040)	(df = 38; 837)
Note:		*p<0.1; **p<0.05; ***p<0.01
		Source: Own Calculation

A.0.7.4 Variance Inflation Factors

Table 65: Variance Inflation Factors for Different Types of Networks:
VIFs test for multicollinearity within the configuration. High multicollinearity is assumed for values over 5.0.

Network type (directed and undirected) full set												
ROA												
Directed	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.25	1.48	1.44	1.42	1.50	1.71	1.51	1.25	2.12	1.91	1.25	
Undirected	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.28	1.39	1.38	1.43	1.52	1.78	1.42	1.25	1.91	1.84	1.58	
Tobin's Q												
Directed	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.28	1.50	1.44	1.42	1.23	1.60	1.95	1.64	1.18	2.28	1.94	1.15
Undirected	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.32	1.43	1.39	1.36	1.17	1.51	1.74	1.37	1.18	1.86	1.78	1.43
Network type (directed and undirected) reduced subsets based on total assets												
ROA												
Direct.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.24	1.49	1.44	1.40	1.53	1.70	1.51	1.25	2.15	1.91	1.26	
Undirect.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	DivPay	EarnDum	DivDum	PopGrwth	ln.GDPPCap	OECD-Aggr	HHI	
	1.34	1.39	1.36	1.44	1.57	1.81	1.44	1.26	1.90	1.88	1.61	
Tobin's Q												
Direct.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.26	1.51	1.44	1.41	1.24	1.63	1.96	1.64	1.17	2.30	1.95	1.15
Undirect.	ln.TotAss	ln.SalesGrwth	ln.DebtGrwth	ln.CapxGrwth	ln.BookPrice	lag(DivPay)	EarnDum	DivDum	ln.PopGrwth	ln.GDPPCap	OECD-Aggr	HHI
	1.38	1.44	1.36	1.36	1.18	1.55	1.75	1.40	1.17	1.85	1.81	1.45

Source: Own Calculation

A.0.7.5 Variances for F-Test or Welch-Test

Table 66: Tests for Variances for Different Types of Networks:
To examine whether different subsets show different means, it has to be tested whether the variances differ. In cases the variances differ the Welch-Test for different means has to be conducted, in cases with similar variance, the F-Test is conducted.

Variable	Data Sets	F	Num df	Denom df	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Ratio of Variance
ROA	direct. & undir.	0.22	8149	2608	2.2E-16	0.21	0.23	0.22
TQ	direct. & undir.	1460.13	8270	2651	2.2E-16	1371.84	1552.55	1460.13
Subsets								
Variable	Data Sets	F	Num df	Denom df	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Ratio of Variance
ROA	direct. & undir.	0.22	7900	2506	2.2E-16	0.21	0.23	0.22
TQ	direct. & undir.	1447.25	8021	2548	2.2E-16	1358.12	1540.62	1447.25

Source: Own Calculation

A.0.7.6 Means for Subset

Table 67: Tests for Means of Reduced Subsets Based on Total Assets for Different Types of Networks:
Here the robustness of the tests of different means is tested. For each subset of vertical integration a reduced subset based on high total assets is created and tests. The means do not differ, comparably to the full subsets.

Data Sets	T	DF	P-Value	95% Conf. Int. Set 2	95% Conf. Int. Set 2	Mean Set 1	Mean Set 2
direct. & undir.	0.56	2861.77	0.57	-9.06	16.38	-2.59	-6.25
direct. & undir.	2.10	8055.80	0.04	0.68	20.08	12.43	2.05

Source: Own Calculation

Appendix B

Literature

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