Infrastructure Investment Characteristics:
Risk, Regulation, and Inflation Hedging

An Empirical Analysis of Listed Infrastructure Firms

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Abstract

Despite the growing interest in infrastructure investments, the empirical evidence on their risk characteristics is limited. To fill this gap, I analyze the investment risk profile, the impact of regulation on risk, and the inflation hedging properties of infrastructure using a proprietary sample of 1,458 listed transport, telecom, and utility firms globally.

The analysis of the risk profile confirms the often cited hypothesis that infrastructure exhibits significantly lower systematic risk than comparable equities. However, total risk is not significantly different for infrastructure firms, contradicting the widespread belief that infrastructure is generally low-risk. Hence, infrastructure is characterized by a high level and share of idiosyncratic risk which can be attributed to construction risk, operating leverage, discretionary regulation, and little internal diversification. Moreover, the risk profiles of different infrastructure sectors are remarkably heterogeneous.

When investigating the impact of regulation, I find that the existence of price regulation significantly reduces systematic risk, affirming Peltzman (1976)'s buffering hypothesis. In contrast to some previous empirical work, I verify the theoretical prediction that incentive regulation entails higher market risk relative to cost-based regulation, but only if jointly implemented with an independent sector regulator. I conclude that politically entrenched regulators appear to fall prey to regulatory capture under incentive regimes. Firms seem to be able to avert the intended risk transfer and the efficiency incentives due to information asymmetries and regulatory gaming. The evidence also shows that autonomous regulators reduce market

risk, suggesting that they curb the scope for political opportunism, foster continuity in price setting, and credibly signal commitment to sunk cost recovery.

Lastly, I provide evidence that listed infrastructure does not generally feature enhanced inflation protection properties relative to equities. This finding stands in contrast to the common investor claim that infrastructure assets are a natural inflation hedge due to their monopolistic pricing power, the regulatory regimes such as RPI-X, and the high share of fixed costs. However, portfolios of infrastructure firms with particularly high pricing power – namely those active in sectors and countries with high entry barriers, vertical integration, and little competition – offer a slightly superior inflation protection in comparison to other equities.

These findings have implications for both investment management and public policy. The low systematic risk exposure of infrastructure assets highlights their diversification benefits for investors' portfolios. The significant idiosyncratic risk calls for sophisticated risk mitigation strategies and tools, the use of financial intermediaries, and adequate risk sharing mechanisms between the public and the private sector. Because of the heterogeneity of the infrastructure asset class, investors need to develop advanced analysis and investment selection capabilities including a profound understanding of the different business models, market environments, and regulatory frameworks. With regard to public policy, the findings point out that governmental financial support schemes may be warranted for socially beneficial infrastructure projects if idiosyncratic risks along with insufficient diversification impede investments. In addition, policy makers should strive for a stable institutional foundation of regulatory independence to foster effective risk allocation under incentive regimes as well as to reduce regulatory uncertainty and the associated risk premiums.

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List of Abbreviations

Abbreviation	Definition
ADR	American Depositary Receipt
AUD	Australian Dollar
Avg	Average
BOO	Build-Own-Operate
BOT	Build-Operate-Transfer
BRIC	Brazil, Russia, India, China
CAPM	Capital Asset Pricing Model
CDMA	Code Division Multiple Access
CPI	Consumer Price Index
DB	Design-Build
DBB	Design-Bid-Build
DBFO	Design-Build-Finance-Operate
DBO	Design-Build-Operate
DV	Dummy Variable
EBIT	Earnings Before Interest & Taxes
EBITDA	Earnings Before Interest, Taxes, Depreciation & Amortization
EIB	European Investment Bank
ETCR	Energy, Transport & Communication Regulation
E.U.	European Union
FAC	Fuel Adjustment Clause
FCC	Federal Communications Commission
GBP	Great Britain Pound
GDP	Gross Domestic Product
GDR	Global Depositary Receipt
GFD	Global Financial Data
GICS	Global Industry Classification Standard
GP	General Partner
GSMA	Global System for Mobile Communications Association
ICB	Industry Classification Benchmark

Abbreviation	Definition
ILEC	Incumbent Local Exchange Carrier
IPO	Initial Public Offering
IRR	Internal Rate of Return
LNG	Liquefied Natural Gas
LP	Limited Partner
MDG	Millennium Development Goals
Med	Median
MRO	Maintenance, Repair, Overhaul
MSCI	Morgan Stanley Composite Index
MVNO	Mobile Virtual Network Operator
NACE	Nomenclature of Economic Activities in the E.U.
NAICS	North American Industry Classification Standard
NCTA	National Cable & Telecommunications Association
NRC	National Research Council
OECD	Organisation for Economic Cooperation and Development
O&G	Oil & Gas
OLS	Ordinary Least Squares
PE	Private Equity
PP	Pricing Power
PPP	Public-Private Partnership
R&D	Research & Development
REIT	Real Estate Investment Trust
ROA	Return on Assets
ROE	Return on Equity
RoR	Rate-of-Return (regulation)
ROW	Rest of the World
RPI	Retail Price Index
RPI-X	Retail Price Index minus Efficiency Increase (regulation)
SIC	Standard Industrial Classification
S&P	Standard & Poor's
SWF	Sovereign Wealth Fund
T&D	Transmission & Distribution
TDS	Thomson Datastream
TSR	Total Shareholder Returns
TWS	Thomson Worldscope
U.K.	United Kingdom
U.S.	United States (of America)
USD	United States Dollar
VIF	Variance Inflation Factor
WGI	World Governance Indicators

List of Symbols

Symbol	Definition
$Adjudicator\_D$	Adjudicator independence dummy
Ask	Share ask price
$Assets$	Total assets
β	Equity (levered) beta
β^{acc}	Accounting beta
β^{Dimson}	Dimson equity beta
β^{n}	Inflation beta based on nominal returns
β^{r}	Inflation beta based on real returns
β^{u}	Asset (unlevered) beta
Bid	Share bid price
$BidAskSpread$	Bid-ask-spread
$BookMarket$	Book-to-market ratio
c	Currency or country index
C	Total number of currencies or countries
$Curr$	Excess returns on local deposits measured in USD
$CAPEX$	Capital expenditure
$CapexVola$	Capital expenditure volatility
$CompanyStatus$	Status of the company (active or inactive)
$CountyGovernance$	Quality of country governance
δ	Volatility of returns
$\delta^{Getmansky}$	Illiquidity-adjusted volatility of returns
δ^{idio}	Idiosyncratic volatility of returns
$DebtBV$	Book value of total debt
$DivPayout$	Dividend payout ratio
$DivPayout\_D$	Dividend payout dummy
ϵ	Regression error term
$EarningsPrice$	Earnings-to-price ratio
$EBIT$	Earnings before interest and taxes
$EbitMarginVola$	EBIT margin volatility

Symbol	Definition
$Emerging\_D$	Emerging market dummy
$EmergingInfra\_D$	Emerging market infrastructure dummy
$EquityBV$	Book value of equity
$EquityMV$	Market value of equity
EP_D	Earnings-price dummy
ER	Exchange rate between local currency and USD
$ExcessKurtosis$	Excess kurtosis of returns
$ExcessKurtosis2$	Outlier-robust excess kurtosis of returns
$FirmValue$	Total firm value
ΔGDP	Real GDP growth
i	Company index
$IncentiveRegulation\_D$	Existence of incentive regulation dummy
$Independence\_D$	Independent regulator dummy
$IndependentIncentive\_D$	Independent incentive regulation dummy
IR	Interest rate
$Leverage$	Leverage (debt-to-equity ratio)
$Licenses\_D$	Licenses independence dummy
M	Total market return
$MarketBook$	Market-to-book ratio
$MarketCompetition$	Market competitiveness
$NetProfit$	Net profit
π	Inflation
$\Delta\pi$	Change of inflation
$\hat{P}_\alpha$	α-percentile of the return distribution
$PriceEarnings$	Price-to-earnings ratio
$PriceRegulation\_D$	Existence of price regulation dummy
$\bar{R}$	Average total shareholder return (annual, nominal)
R	Total shareholder return (annual, nominal)
R^n	Nominal total shareholder annual return (annual)
R^r	Real total shareholder return (annual)
$RelTradVol$	Relative trading volume
$ReturnIndex$	Total shareholder return index
ROA	Return on assets
ROE	Return on equity
$RuleMaking\_D$	Rule making independence dummy
$SalesGrowth$	Annual sales growth
$Sales$	Sales
$SalesVola$	Sales volatility
$Sanctions\_D$	Sanctions independence dummy
$Shares$	Number of shares outstanding
$SICs$	Number of SIC codes

Symbol	Definition
$Skew$	Skewness of returns
$Skew2$	Outlier-robust skewness of returns
t	Time index
T	Total length of respective data time series
Tax	Corporate tax rate
$TradingVolume$	Trading volume of shares
$TradCont$	Trading continuity

Chapter 1

Introduction

1.1 Motivation

Infrastructure as an asset class has experienced a steady rise of investor interest over the past decade. Pension and private equity funds as well as banks and insurance companies have initiated allocations to this relatively new alternative asset class. Their demand is driven by the desire to invest in assets with stable cash flows, little market correlation, and an overall attractive risk-return profile. Another motive of infrastructure investing is to match long-term liabilities and to protect against inflation, which is of particular concern to pension funds and insurance firms. Infrastructure assets promise such investment features due to the regulated environment and the essential good and natural monopoly characteristics.

At the same time, governments around the world urged by mounting fiscal pressure and the belief in a superior operational performance of private infrastructure operators created the necessary legislative and institutional framework for private sector involvement in infrastructure delivery. Governments privatized assets through initial public offerings, public sales, or Public-Private Partnerships (PPP). According to the Privatization Barometer, 640 privatization transactions, cumulatively worth more than \$3 trillion, involving transportation, utility, and telecommunication firms were completed between 1980 and 2008 just in Europe.[1] In addition, an increasing number of greenfield projects were financed and developed by the private sector. Some notable examples include the construction of the Channel rail crossing, the new Athens airport, and the roll-out of third-generation mobile networks around the world.

The increasing demand and supply of infrastructure assets created a flourishing market for private infrastructure finance. For example, the number of listed infrastructure firms rose from 216 to 1,136 between 1980 and 2010.[2] This market momentum is also represented by the dynamic development of investment funds specializing in the asset class. While only a handful of pioneering infrastructure funds such as Macquarie started fundraising in the 1990s, in September 2010 there were already 111 unlisted funds seeking an aggregate capital of $80 billion (Orr (2007), Preqin (2010b)). The growing number of funds also came along with an increase of the average fund size and a proliferation of the fund variety in terms of target sectors and geographies (Preqin (2008)). Besides unlisted funds, the market for listed infrastructure funds on the Australian Stock Exchange – the stock exchange with most listed infrastructure funds globally – also skyrocketed from only five funds with a combined market capitalization of less than AUD 2 billion in 1999 to 20 funds worth AUD 36 billion (Colonial First State (2006b)).

Though private investments are increasingly complementing the traditionally dominating public finance, the state of the infrastructure endowment in many countries around the globe is still dire. OECD (2007) estimates that total investments of $71 trillion (or 3.5% of global GDP) are required for telecommunication, energy, water, road, and rail infrastructure from 2007 till 2030. While emerging countries need to build the necessary infrastructure to support growing populations, rapid urbanization, and rising income levels, the financing needs in developed countries are focused on rehabilitation and upgrade projects as maintenance budgets have been

[1] Source: www.privatizationbarometer.net. Retrieved on 5 November 2010. The definition of transportation in the Privatization Barometer also includes service operators, e.g. airlines, besides infrastructure providers.

[2] Data are based on the infrastructure firm sample introduced in chapter 4 as of 31 December 1979 and 31 December 2009.

chronically underfunded and many infrastructure assets are approaching the end of their life cycle. The environmental policies to foster the transition to a greener energy and transportation system pose an additional financing challenge. Since current spending levels on infrastructure are insufficient to accommodate for these needs and as fiscal budgets are constrained in the aftermath of the global financial crisis, it is crucial to attract private finance to close the looming infrastructure gap.

Despite the growing interest and need for private infrastructure investments, the empirical studies on the investment characteristics of this alternative asset class are limited in quantity and quality. It remains ambiguous whether the ex-ante investor expectations with regard to the overall investment risk profile, the risk features of a regulated business, and the inflation hedging properties actually materialize. Therefore, a thorough empirical verification of these infrastructure investment propositions is paramount to inform current investors' strategies, but also to attract additional funds to these economically relevant, yet underfunded assets. Besides financiers, operators as well as governments and regulators have a vivid interest in the de-facto investment characteristics of the assets that they manage, privatize, or regulate.

1.2 Research objectives and contribution

This dissertation aims to contribute to a more profound understanding of the investment characteristics of the emerging infrastructure asset class. The starting point of my research are some widely cited hypotheses in academia and the investment community about the infrastructure risk properties, which are not yet empirically corroborated. First, theoretical economic reasoning and conventional investor wisdom assert that infrastructure has low total and systematic risk. Secondly, regulatory theory predicts that the application of price regulation and the presence of independent regulatory authorities decrease systematic risk, while incentive regulation presumably increases systematic risk relative to cost-based regulation. Thirdly, infrastructure investments are claimed to serve as a natural hedge against inflation. I aim to provide empirical evidence for these hypotheses on the investment risk profile, the impact of regulation on systematic risk, and the inflation hedging features by analyzing the following research questions in the course of this thesis:

1. What is the investment risk profile of infrastructure and its (sub-)sectors? How does the corporate, systematic, and idiosyncratic risk exposure of infrastructure compare to market-average equity investments?

2. What is the impact of infrastructure regulation on systematic risk? How do price regulation, the regulatory regime, and regulatory independence affect market risk?

3. What are the inflation hedging properties of infrastructure? Does infrastructure provide enhanced inflation protection relative to market-average equities?

This dissertation contributes to the emerging body of literature on private infrastructure finance. First, it sheds light on the investment risk profile of infrastructure investments, where empirical evidence is limited. In contrast to previous studies, both idiosyncratic and systematic risk are analyzed in a statistically sound approach using a large dataset of listed infrastructure firms representing all world regions and sectors of economic infrastructure. Secondly, this thesis contributes to the strand of the political economy literature on price regulation. It examines the Peltzman (1976) hypothesis – that price regulation buffers market risk – for a cross-country and cross-sector dataset of infrastructure firms for an increasingly deregulated market context. It also investigates the impact of the regulatory regime and regulatory independence and their interaction on systematic risk, where previous empirical research is inconclusive or missing. Thirdly, this study contributes to the inflation hedging literature as it is the first to investigate the inflation hedging properties of infrastructure in a methodologically robust analysis with a sufficiently long time series of infrastructure returns across multiple currencies. For all above analyses a proprietary sample of thoroughly selected pure-play infrastructure firms is used.

The insights of this thesis are relevant for various infrastructure stakeholders and have implications for both investment management and public policy. Investors and asset managers appreciate an improved risk assessment for performance evaluation and for asset allocation decisions to or within the infrastructure asset class. A better understanding of these risk properties by investors lessens the information gap on this alternative asset class and thus contributes to channeling additional funds to infrastructure. The results also highlight which risk management strategies and investment screening capabilities are relevant for successful infrastructure investing. Managers of infrastructure firms may use these insights to improve business unit capital allocations and investment decisions, the valuation of M&A targets, and for regulatory negotiations. Governments get a better understanding of the risks of public infrastructure investments and the risk exposure potentially shifted to the private sector. The findings also support regulators in determining fair regulated prices by appropriately including risk charges in the costs of capital. In addition, the results provide lessons for the design of coherent regulatory policies and institutions. Implementing such conducive regulatory frameworks would increase economic efficiency and attract further private investments to shrink the global infrastructure financing gap.

1.3 Structure of thesis

The organization of this dissertation is as follows. Chapter 2 contains a brief overview of (private) infrastructure finance. After providing a definition of infrastructure, the macroeconomic relevance of infrastructure and different forms of infrastructure financing are discussed to provide a context for this thesis. The role of private finance in addressing the global infrastructure gap is particularly highlighted and some features of the private investment market are explicated. Chapter 3 surveys the existing literature on the investment characteristics of infrastructure.

Economic theories and previous empirical evidence are discussed. Based on this review, testable hypotheses for the subsequent empirical analyses of the investment risk profile, the risk impact of regulation, and the inflation hedging properties of infrastructure are derived. The sample of listed infrastructure firms that is used to empirically investigate these research questions is introduced in chapter 4. The constitution of the infrastructure and a reference sample of benchmark firms is presented, along with the utilized firm- and country-level datatypes and their respective sources and definitions. In chapter 5 the investment risk profile of infrastructure is analyzed empirically. Both corporate and market risk exposure of infrastructure are compared to equities using a descriptive and an econometric approach. In chapter 6 the impact of price regulation, the regulatory regime, and regulatory independence on systematic risk is examined. Chapter 7 studies the inflation hedging properties of infrastructure relative to equities. Finally, chapter 8 concludes and outlines possible future research directions.

Chapter 2

Private Infrastructure Finance: An Overview

This chapter provides some basic facts about (private) infrastructure finance useful in the context of this thesis. First, a definition of infrastructure is given, which is also used as the basis for the sample set-up. Next, the economic relevance of infrastructure and the global infrastructure investment needs are outlined. The chapter concludes with an overview of alternative infrastructure delivery and financing models, with a particular emphasis on the equity finance market which is analyzed in this thesis.

2.1 A definition of infrastructure

The Oxford Dictionary defines infrastructure as the "basic physical and organizational structures and facilities [...] needed for the operation of a society or enterprise".[1] This generic definition includes both "hard" physical assets and "soft" institutions such as the financial system, the education system, the health care system, the law enforcement system, and the emergency services. It also comprises

[1]Source: www.oxforddictionaries.com. Retrieved on 20 February 2012.

both assets that are publicly accessible to all users and facilities dedicated to firm-specific purposes. The functional definition of the OECD (2007), which defines infrastructure as the "means for ensuring the delivery of goods and services that promote prosperity and growth and contribute to quality of life, including the social well-being, health and safety of citizens, and the quality of their environments", has a similarly broad scope. Both of these definitions are not conducive in an asset management context, since some of their components are not investable physical assets that generate cash flows from external users.

However, a single dominant definition of infrastructure has not yet emerged in the asset management literature.[2] But many authors have adopted the National Research Council (1987)'s (NRC) definition, which stipulates that "public works infrastructure includes both specific functional modes - highways, streets, roads, and bridges; mass transit; airports and airways; water supply and water resources; wastewater management; solid-waste treatment and disposal; electric power generation and transmission; telecommunications; and hazardous waste management - and the combined system these modal elements comprise."[3] According to this definition, infrastructure does not only comprehend these public works facilities, but also the operating procedures, management practices, and development policies that facilitate the transport of people and goods, provision of water, disposal of waste, provision of energy, and transmission of information. Hence, this definition excludes firm-specific infrastructure, "soft" infrastructure as well as social infrastructure assets such as healthcare, education and judicial facilities. It only refers to economic infrastructure consisting of all physical assets for transport, telecommunications as well as power, gas, and water supply, for which users mostly have to pay for – in contrast to social infrastructure which is usually provided for free or

[2]The economics literature provides several definitions of infrastructure, e.g. Jochimsen (1966), Aschauer (1989), and Buhr (2003). The project finance literature distinguishes between stock- and flow-type projects, where stock-type projects generate cash flows from resource extraction, while flow-type projects derive income from asset usage (Bruner and Langhor (1995)). Various other disciplines, ranging from information technology to the military, have also developed their context-specific definitions.

[3]The name "public works infrastructure" does not necessarily imply public financing of the infrastructure.

at a subsidized rate (Colonial First State (2006b)). This definition is useful in an asset management context as it focuses on physical investable assets that generate cash flows from external users. Moreover, it also includes the processes, structures, and systems that are required for asset operation and value generation, and thus form an essential part of the business model of infrastructure firms.

Despite the fact that many authors in the investment literature refer to the NRC definition, there is disagreement with regard to which infrastructure sectors should actually be included. For example, the NRC definition does not mention ports, which other authors consider as infrastructure. Hence, this definition needs to be supplemented by a more complete enumeration of infrastructure sectors. For this purpose, I survey often cited publications on infrastructure investing (Inderst (2009), Colonial First State (2006b), RREEF (2005)) and the most widely used infrastructure indices (MSCI World Infrastructure, S&P Global Infrastructure[4], Dow Jones Brookfield Global Infrastructure, UBS Global Infrastructure & Utilities, Macquarie Global Infrastructure) to obtain a commonly accepted list of infrastructure sectors. As presented in Table 2.1, the majority of the surveyed publications and indices consider the following sectors and subsectors[5] as infrastructure:

- Telecom: satellite, wireless, fixed-line, cable
- Transport: airports, ports, highways[6], railways, pipelines[7]
- Utilities: generation, transmission and distribution of electricity, water[8], and gas

This broad sector scope – which is also used for the World Bank's "Private Participation in Infrastructure" database – ensures that no asset types are disregarded and addresses the recommendation of Peng and Newell (2007) that further

[4]Refer to MSCI Barra (2008) and Standard & Poor's (2009) for further information on these indices.

[5]In the context of this thesis, transport, utilities, and telecom are referred to as sectors, whereas the secondary level (e.g. ports, airports) is referred to as subsectors.

[6]Including bridges and tunnels. Excluding parking.

[7]Including oil and gas storage terminals.

[8]Including sewerage systems.

studies should assess the "full spectrum of infrastructure investments" including sectors such as "communication, generation, transmission and distribution" in order to overcome the limitations of previous research. Notwithstanding, a de-averaged analysis still permits to highlight sector-specific risk characteristics.

Table 2.1: Infrastructure definitions

	Publications			**Indices**					**Summary**
	Inderst 2009	RREEF 2005	CFS 2006	S&P	MSCI	DJ Brookfield	UBS	Macquarie	
Telecom									
Satellite	yes	yes	yes	no	no	partly	partly	partly	yes
Wireless	yes	no	yes	no	yes	partly	partly	partly	yes
Fixed-line	yes	yes	yes	no	yes	partly	partly	partly	yes
Cable	yes	yes	yes	no	no	partly	partly	partly	yes
Transport									
Airports	yes	yes	yes	yes	yes	yes	yes	yes	yes
Ports	yes	yes	yes	yes	yes	yes	yes	yes	yes
Highways	yes	yes	yes	yes	yes	yes	yes	yes	yes
Rail	yes	yes	yes	yes	yes	no	yes	yes	yes
O&G pipelines	yes	no	no	yes	yes	yes	yes	yes	yes
Utilities									
Electricity Gen.	yes	yes	yes	yes	no	no	yes	yes	yes
Electricity T&D	yes	yes	yes	yes	yes	yes	yes	yes	yes
Water	yes	yes	yes	yes	yes	yes	yes	yes	yes
Gas	yes	yes	yes	yes	yes	no	yes	yes	yes
Waste/refuse	no	no	no	no	no	no	no	no	no
Social									
Healthcare	yes	yes	yes	no	yes	no	no	no	no
Education	yes	yes	yes	no	yes	no	no	no	no
Judicial	yes	yes	yes	no	no	no	no	no	no

Notes: "O&G" stands for Oil & Gas; "Gen." stands for generation; "T&D" stands for transmission & distribution.
Source: Author

Note, that the above extensional definition only includes sectors of economic infrastructure. Social infrastructure (e.g. hospitals, schools, prisons) is not included as most publications and indices also ignore it. In any event, an empirical analysis of its risk characteristics is difficult as projects are usually put to tender as Public-Private Partnerships (PPP), effectively limiting the number of listed firms representing this sector. Moreover, the sector has fundamentally different risk and return characteristics than economic infrastructure (Deloitte (2011)). Long-term lease contracts with governments assure a stable cash flow profile rather resembling real estate assets. In addition, the government usually remains the operator of the associated services such as the prison, the hospital or the judicial facility and hence operational and patronage risks are not under private control. The fact that consumers are often not charged as services are subsidized gives another reason for the supposedly distinct risk features of social infrastructure.

The above enumeration of sectors frames infrastructure from a horizontal industry perspective. But it does not yet provide a sufficiently precise definition as each of these sectors comprises a variety of economic activities along its respective vertical value chain. For example, the ports sector includes operators of port facilities such as piers and terminals as well as providers of ancillary port services such as tugging, fuelling, and ship maintenance. For this reason, a vertical delineation of infrastructure activities is required. Knieps (2007)'s classification of value chain layers within network industries is well suited to differentiate among these activities:

- Layer 1: Public resources (e.g. land, sea, air, space)
- Layer 2: Physical infrastructure (e.g. airport, railtrack, telecommunication cable, electricity grid)
- Layer 3: Infrastructure management (e.g. air traffic control, rail signaling and control, telecommunication network operations)
- Layer 4: Network services (e.g. passenger air service, cargo rail, provision of phone service, sale of electricity)
- Layer 5: Related services and products (e.g. construction, ground-handling, network engineering, power plant maintenance)[9]

This framework is used to classify all activities that are part of the previously enumerated infrastructure sectors. Expert interviews were used to derive the clas-

[9]The fifth layer is not part of the original Knieps (2007) model, but it is a useful extension to capture infrastructure related products and services.

sification into the five value chain layers as presented in Table 2.2. For example, for highways the required public resource is land; the physical infrastructure are roads, bridges, and tunnels; the infrastructure management consists of traffic control systems (e.g. traffic lights, speed control); the network services are either passenger- (bus, taxi, car) or freight-related transportation operations (trucking, postal); and related services and products include highway construction and maintenance, parking, roadside restaurants, and fuel stations. While the earlier activities of layers 1 to 3 are considered core infrastructure, the activities of the latter two layers (network services, related services and products) are not regarded as core infrastructure businesses in the context of this thesis.[10]

In summary, I use the following definition of infrastructure:

- Infrastructure firms are owners or concessionaires of any physical infrastructure asset (including the public resources and the associated management systems)
- that is accessible to all potential users (i.e. firm-specific infrastructure is excluded) and thus generates external cash flows
- and that is part of the following sectors of economic infrastructure: Telecommunication (satellite, wireless, fixed-line, cable); Transport (airports, ports, highways, rail, pipelines); Utilities (generation, transmission and distribution of electricity, water, and gas).

2.2 Economic relevance of infrastructure

Economic theory suggests that infrastructure plays an important role for the performance of an economy. Well designed infrastructure "facilitates economies of scale, reduces costs of trade, and is thus central to specialization and the effi-

[10]Note, that in practice most infrastructure firms bundle the public resources (layer 1), the physical assets (layer 2), and the associated management systems (layer 3). However, in some vertically integrated industries such as railroads, electricity and telecommunication many firms include layers 1 to 4. Refer to section 4.1.3 for details on the identification procedure for core infrastructure sample firms.

Table 2.2: Infrastructure value chain by subsector

Sector	Layer 1 Public resources	Layer 2 Physical infrastructure	Layer 3 Infrastructure management	Layer 4 Network services	Layer 5 Related services & products
Satellite	Land, space, air	Satellites, earth stations	Satellite control	Satellite TV/radio stations, asset tracking & positioning systems	Media content, satellite equipment & software, space transport
Wireless	Land, air (frequency licenses)	Base stations, towers	Network operations center incl. switches	Phone & data services (incl. billing, marketing), esp. MVNOs, resellers, value-added services	Media content, network engineering, software & hardware, mobile phone distribution
Fixed-line	Land	Fixed line network (last mile & backbone / copper & fibre)	Network operations center incl. switches	Phone & internet services (incl. billing, marketing), esp. resellers	Media content, network engineering, software & hardware
Cable	Land	Cable network	Network operations center	TV & radio stations, phone and internet services	Media content, network engineering, software & hardware
Airports	Land, air (flight corridors)	Airports, flying fields, terminals within airports	Air traffic control, apron & positioning & slot coordination	Cargo & passenger airline, helicopter services	Ground-handling, catering, fueling, aircraft manufacturing & leasing & MRO, airport construction & equipment
Ports	Land, sea (shipping lanes)	Sea & inland ports, terminals within ports, locks, canals	Navigation service (incl. lighthouses), traffic control, lock operations	Cargo shipping, ferry line	Tugging, warehousing, fuelling, dredging & other off-shore services, brokerage, ship & container manufacturing & leasing & MRO
Highways	Land	Roads, bridges, tunnels, toll houses, exchanges	Traffic control, traffic management, tolling	Passenger transport (bus, taxi, car), freight transport (trucking, postal service)	Parking, roadside restaurants, fuel stations, highway maintenance/cleaning, highway construction & equipment
Rail	Land	Superstructure & electrification, (intermodal) stations, shunting yards	Rail control and security, track allocation	Passenger and cargo rolling stock operations (without own tracks)	Freight forwarding, Rolling stock manufacturing & MRO & leasing, tracks construction & equipment & MRO
Pipelines	Land	Product pipelines, raw product pipelines, storage facilities (incl. LNG)	Flow and quality control, capacity allocation	Sale and trading of gas	Pipeline construction & MRO, equipment supply, Oil & Gas exploration & production
Electricity	Land	Electricity generation plants, transmission & distribution grid, transformers	Network management & control (incl. smart grid)	Marketing & sale of electricity (esp. resellers), metering services	Industrial services, power plant construction & MRO, equipment supply
Water utilities	Land, water	Facilities for water extraction & storage & treatment, distribution & collection pipes	Flow and quality control	Marketing & sale of water, metering service	Purification & treatment technology, construction & MRO, waste disposal/collection
Gas utilities	Land	Gas transmission & distribution network, storage facilities (incl. LNG)	Network management & control	Marketing & sale of gas (esp. resellers), metering services	Industrial services, construction & MRO, equipment supply, gas exploration & production

Note: This table does not represent a complete overview of all value chain activities in each sector, though it covers the most relevant activities required for the firm classification.
Source: Author

cient production and consumption of goods and services" (Henckel and McKibbin (2010)). Infrastructure services such as energy and water supply, transportation and communication are quintessential input factors for any kind of economic activity. Absent or unreliable infrastructure implies an additional cost burden as firms are required to establish their own means of supply. But since investing in firm-specific infrastructure is inherently inefficient due to the significant fixed costs, the provision of public infrastructure entails economies of scale and a productivity effect for firms. As a consequence, an adequate regional infrastructure endowment lowers transaction costs (direct costs, time needs, and delivery risks) for the exchange of goods and information, and thus facilitates trade and comparative advantages. It may also abolish regional monopolies by enabling the exchange of information, labor, energy, and products. Moreover, high-density cities and their agglomeration economies based on shared resources, knowledge spillovers, and liquid markets are only conceivable with adequate urban infrastructure. These facilities such as mass transit and water/sewer systems are paramount to urban life as they mitigate the costs of density including congestion, noise, waste, and diseases. Because of the above reasons, both regional and urban infrastructure has a significant multiplier effect on other industries as they provide a key prerequisite for the economy to function efficiently.

There is plenty of anecdotal evidence demonstrating the positive impact that infrastructure has on the macro-economy and the micro-level livelihoods of people. For instance, insufficient or irregular power supply reduces GDP by 1-2% in India, Pakistan and Colombia (International Finance Corporation (1996)). In African countries, the lack of water infrastructure means that significant time – up to 60 minutes per day – is spent for water collection (Rosen and Vincent (1999)). The historic example of the construction of the Erie Canal through New York State also provides evidence for the positive impact of infrastructure development, as it slashed the transportation costs of wheat to the coast by 90% (Engerman and Sokoloff (2006)). The availability and quality of infrastructure also affects the location decision of firms, as 90% of senior executives agree consistently around the world (KPMG (2009)). For example, AT&T moved its headquarters from San Antonio to Dallas in 2008, in part because of the latter's better air transportation links (KPMG (2009)).

Besides the economic arguments and the anecdotal evidence, empirical econometric studies on the infrastructure growth nexus also largely support the positive welfare effect (Romp and de Haan (2005), Briceno-Garmendia et al. (2004)). Aschauer (1989) pioneered this field and revealed particularly high economic returns to infrastructure as his evidence indicates that for every 1% change in the government infrastructure stock, private output responds by 0.4%. However, his and other early estimates are plagued by over-estimation bias as higher income may also cause higher demand for infrastructure services. Subsequent research disentangles this endogeneity, but the results still broadly confirm the significance of infrastructure for economic growth. Calderón et al. (2011), for example, provide a methodologically robust estimate of the output elasticity of the infrastructure stock, indicating that a 1% rise in infrastructure assets increases GDP per capita by around 0.1%, which is also in line with recent estimates from meta-studies (Bradley et al. (2011)). Another estimate of the infrastructure multiplier by Zandi (2009) focuses on spending as opposed to the infrastructure stock: Each dollar invested in infrastructure boosts GDP by $1.59. Despite the widespread evidence on the positive macroeconomic impact of infrastructure, the findings on the magnitude of the effect differ. This is not unsurprising as the relevance of infrastructure for economic prosperity varies across countries and over time, depending on network effects, project characteristics, and other binding constraints. The positive effects of infrastructure on output, productivity, and employment is consistently larger at lower levels of income and in developing countries (Briceno-Garmendia et al. (2004)). Moreover, positive network externalities, i.e. increasing utility to users as the number of users increases, imply non-linear returns to infrastructure. The highest impact is achieved when a network is sufficiently developed, though not yet completed (Canning and Bennathan (2000)). For example, the net social return for the U.S. Interstate Highway System was about 35% in the 1950s and 60s, and declined to about 10% in the 1980s as the marginal gains of connectivity and accessibility in a maturing network abated (National Cooperative Highway Research Program (2006)). Similarly, Roller and Waverman (2001) find that the economic impact of telecommunication is highest when penetration approaches universal coverage. Infrastructure projects are also highly heterogeneous with regard to their asset characteristics and the underlying decision making process. Politically motivated projects, such as "Alaska's bridges to nowhere", may not face a real market test and thus not provide the desired economic benefits. Moreover, the economic benefits of new infrastructure often occur with a lag as firms and people adjust their behavior slowly to new facilities. If other binding constraints such as institutional factors or the degree of liberalization and competition hamper economic development, new infrastructure development may also not entail a positive productivity effect.

Infrastructure is also a vital ingredient for social development, as it is indispensable for the existence and well-being of a society. Besides gross domestic product, infrastructure has a positive impact on a wider set of measures for living standard, including access to health services and education facilities. For example, Brodman (1982) finds that access to electricity allows children to study longer, and Lebo and Schelling (2001) provide evidence that literacy rates are higher in villages with better road access. A study of the World Bank (1996) shows that improved road connectivity also leads to better health outcomes, similar to better water and sanitation infrastructure (Jalan and Ravallion (2001), World Bank (2000)). Access to water infrastructure also features prominently in the United Nations' Millennium Development Goals (MDG)[11], while other types of infrastructure are required to support the MDGs targeting universal education, maternal and child health, and environmental sustainability.

[11] Target 7.C: Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation.

2.3 Global infrastructure investment needs

2.3.1 Demand for infrastructure

Demand for infrastructure is on the surge globally. This trend is driven by a confluence of different factors including the growing global population, progressing urbanization, and increasing wealth. The global population has just hit the 7 billion mark in late 2011 and is expected to grow further at a rate of 0.7% and surpass 9 billion by 2050 – although the population in advanced economies is anticipated to remain about constant (United Nations (2011)). Asia and Africa are expected to experience the largest absolute population growth, which entails a significant increase in infrastructure requirements to satisfy the basic human and corporate needs in terms of water, energy, mobility and communication. Besides the growing population, increasing urban densities also boost the demand for infrastructure. Urbanization is expected to proceed continuously as rural dwellers move to cities to pursue economic and social opportunities. While the world rural population is already essentially at its peak, the urban population will double until 2050, adding another three billion people to the world's cities. In China alone, in just the next 20 years, 300 million people will become urbanized, equal to the entire population of the U.S., the world's third most populous country. Higher urbanization increases demand for infrastructure to cope with the costs of density, such as congestion, pollution, and diseases. Rising wealth and living standards are also contributing to the growing infrastructure needs. Higher per capita incomes imply an increasing demand for motorized transport at the expense of non-motorized trips and more discretionary trips, such as tourist travel and shopping sprees. Similarly, demand for communication and energy soars. With progressing wealth the average household size tends to shrink, additionally posing a challenge to strained infrastructure systems as more distinct housing units need to be connected to the electricity and telecom grids, and household level scale economies with regard to energy consumption and shopping trips abate.

Besides the soaring demand for infrastructure capacity, technological advances, increasing environmental concerns, and maintenance needs also add to the investment requirements. New technologies such as the smart grid, broadband networks, and high-speed rail need to be financed to provide enhanced services. To address concerns about increasing levels of carbon dioxide in the atmosphere, large investments in regenerative energy generation capacity (e.g. solar, wind, bio mass) and environmentally friendly modes of transport are required. In addition, maintenance and rehabilitation needs are expected to rise in developed countries as their transportation and energy infrastructure, which was built after World War II, is approaching (or has already exceeded) its technical and economic life.

2.3.2 Supply of infrastructure

The rate of infrastructure spending relative to the GDP continuously declined in most developed countries over the past 40 years. For example, while Australia, Canada, and Germany spent more than 4.0% of GDP on infrastructure in the 1960s and 1970s, the spending declined to less than 2.5% in the 1990s and 2000s (Chan et al. (2009)). Even more dramatically, the U.K. public infrastructure investments fell from 5.7% to 1.4%.[12] Though the lower investments are partially justified by lower economic growth, a shifting focus from the industrial to the service sector, and fully built-out infrastructure systems, many countries are underspending relative to their maintenance and expansion needs. Though emerging countries have raised their spending levels to between 3% and 7% over the past decades, the strong population and economic growth calls for investments in the range of 7% to 9% of GDP (Kikeri and Kolo (2005)).

As a consequence of the insufficient spending, the actual supply in terms of railtracks, roads, waterways, airports, fixed-line and mobile networks, electricity generation capacity, electricity transmission and distribution lines, and water treatment plants and distribution networks remained relatively flat – despite a strongly

[12] In the E.U., about 57% of infrastructure investment are on transport, 18% on utilities, 15% on health, and 10% on education (Wagenvoort et al. (2010)).

increasing demand.[13] No new airports are being planned in the U.S. and in Europe, despite the fact that most major airports are operating close to their capacity limit (Stalk (2009)). Though rail freight traffic increased by 12% in Western Europe and 14% in North America from 2003 to 2008, the rail network remained constant – or even shrank in some countries (e.g. the U.K., the U.S., and Germany).[14] Container volumes in U.S. ports have been growing 27% over the last ten years, already outstripping capacity in 2010 (The Boston Consulting Group (2011)). Also road congestion in many countries (e.g. in the U.K., the U.S., China, Indonesia, and India[15]) and megacities (e.g. Beijing, Mexico City, New Delhi, Moscow, Johannesburg, and Sao Paulo) is growing, as road and mass transit developments lack behind. Chinese and Indian cities are experiencing recurring electricity shortages – 9% on average and 40% during peak hours in India (The Boston Consulting Group (2010)). Moreover, 13% of the world population do not have access to an improved water source and basic sanitation, while an even higher share is affected by serious water shortages and quality problems (United Nations (2010)).

The insufficient investments in infrastructure capacity and the deteriorating quality of existing assets, lead to a general dissatisfaction with the infrastructure endowment. Only 14% of 328 executives and board members rate the infrastructure in their country as "completely adequate" (KPMG (2009)). Even in the most positive region, Western Europe, only 24% say the same. Most respondents deem infrastructure "somewhat adequate" (57%), while 18% of the total and 35% of BRIC-based managers are concerned that it is inadequate. In India and Brazil the inadequate supply of infrastructure is considered the most problematic factor for doing business by 17% and 15% of the key decision makers (World Economic Forum (2011)).

[13]Estache and Goicoechea (2005a) provide an extensive overview of data sources for infrastructure sector performance.

[14]Based on author's calculations using Euromonitor data (Length in km of public railway network operated; Goods carried by rail in million tonnes).

[15]For example, in India 40% of villages do not have all weather access roads, and most freight traffic is carried on just 58,000 km of mostly two-lane highways (World Bank (2004)).

2.3.3 Infrastructure funding and financing gap

The dire state of the infrastructure stock in combination with the projected demand growth, poses a serious funding and financing challenge.[16] The OECD (2007) quantifies the global cumulative infrastructure funding need until 2030 to $71 trillion or 3.55% of the world's yearly GDP.[17] This exceeds both the current investment level and the previous estimate for the period from 2000 till 2010 of 2.07% of annual global GDP (Fay and Yepes (2003)). In addition to these econometric estimates, bottom-up engineering models present a similarly gloomy picture for select countries. To bring the U.S. infrastructure to a good condition $2.2 trillion are required over five years, while the spending is forecast at $900 billion (American Society of Civil Engineers (2009)). For the U.K., McKinsey (2011a) estimates that infrastructure investment of GBP 350 billion are required, corresponding to a 45% increase on the average annual spending since the turn of the 21st century. But the pattern of infrastructure requirements will be highly distinct across countries and regions. While emerging markets primarily necessitate new infrastructure due to a growing population, progressing urbanization, and increasing wealth, developed countries' aging and capacity constrained infrastructure needs replacement, rehabilitation, and technical upgrades. But even within countries the challenges vary. In some U.S. metropolitan areas such as New York and Los Angeles infrastructure constrains further growth, whereas Detroit with its shrinking population[18] rather has to cope with a large legacy infrastructure that is cost-inefficient at the current population level.

From the above numbers it becomes obvious that the scale of the global infrastructure investment demand is enormous. The growing need to maintain or replace existing infrastructure and to expand capacity presents an unprecedented challenge

[16]While funding refers to the sources that finally pay for the infrastructure project over the life cycle, financing is the process of raising money up-front in order to carry out the capital investment.

[17]This estimate includes telecom, energy, water, road, and rail infrastructure, but excludes airports, ports, and social infrastructure.

[18]Population was reduced from 2 million in 1970 to 0.7 million in 2010. Source: The Economist, 22 October 2011.

to countries around the world. However, traditional public funding sources have been unable to keep pace with this global investment need. Moreover, current economic conditions, the high public debt burden, and the debt crisis in some developed countries are likely to increase the funding and financing challenges for the foreseeable future. As a consequence, many states are responding by delaying investments and even routine maintenance work, leading infrastructure quality to deteriorate and congestion to grow. The resulting infrastructure funding gap is worrisome due to the instrumental role that infrastructure plays for the wider economy. Given the importance of well-performing infrastructure systems to economic growth and quality of life, finding sustainable solutions is imperative.

To meet these future requirements despite strained government budgets, several approaches are conceivable:

- Increase the effectiveness of infrastructure project prioritization and selection
- Increase revenues by higher taxes, marginal cost pricing, innovative funding mechanisms, and ancillary revenue sources
- Reduce delivery costs by improving construction and operations productivity
- Increase throughput capacity of existing assets through innovations
- Attract private finance to close the financing gap

To increase the effectiveness of project prioritization and selection, governments need to develop long-term strategic infrastructure plans that are aligned with other development policies. Stringent cost-benefit analysis quantifying the internal and external costs and benefits including safety, environmental, and social impacts, is required to prioritize those projects that provide the most economic impetus (Small (1999)).

Revenue increases could be either driven by additional taxes, user charges or other innovative funding mechanisms such as ancillary revenues and land value capture. Since general taxes do not provide any consumer incentives to use infrastructure efficiently, marginal cost pricing is preferred to maximize economic efficiency and welfare. Currently, user prices are often below delivery and externality costs and are unsustainable to recover investments. For example, economic analyses suggest that doubling the gas tax in the U.S., i.e. pricing the significant externalities of transport[19], is economically efficient and would provide sufficient funds for road and mass transit projects around the country (Parry and Small (2005)).[20] Similarly, by charging market prices for curb-side parking in dense urban areas, significant revenues could be collected while parking shortages, traffic congestion, air pollution, energy consumption, and urban sprawl could be alleviated (Shoup (2005)). However, marginal cost pricing approaches are often difficult to implement politically as they draw public opposition as the poor and disadvantaged may be excluded.[21] In addition, innovative sources of infrastructure funding such as ancillary revenues (e.g. retail or advertising at airports) or land value capture can be used to generate additional cash flows from infrastructure assets. Land value capture extracts a part of the higher property values based on infrastructure development through various mechanisms in order to fund infrastructure development.[22]

In addition to increasing funding, there is tremendous scope to shrink the funding gap by fostering greater efficiency in construction and operations. The cost reduction potential is mostly not yet exhausted as there has not been enough economic and competitive pressure over the last several decades to improve performance or to innovate. Standardization of design and investment decision making, optimization of capital expenditure and maintenance for total cost of ownership,

[19]Externalities include traffic congestion (2% of U.S. GDP), greenhouse gas emissions (1-10%), accident deaths and injuries (2%), air pollution (0.4%), noise (0.3%), resource consumption, and energy dependency. For a detailed overview of externality estimates refer to Greene and Jones (1997) and Quinet (2004).

[20]Effectively, a subsidy is granted to motor-users in the U.S. of about 10-70 cents per gallon (Delucchi (2007), Delucchi and Murphy (2008)).

[21]Moreover, if marginal costs are below average costs, operators incur unsustainable losses, e.g. for railtracks marginal prices only cover 5-10% of total costs (Rothengatter (2003)). Another issue are economies of scope when multiple users share the indivisible infrastructure (e.g. trucks and cars) and when it is difficult to allocate costs to each user.

[22]Land value capture mechanisms include special assessment districts, tax increment financing, joint development, and development impact fees. For example, U.S. transit investments entail a value gain of 2-32% for residential, 9-120% for office, and 1-167% for retail properties based on improved accessibility and density and reduced pollution (Center for Transit-Oriented Development (2008)).

and incorporating elements of lean administration could reduce costs by about 15-20% (McKinsey (2011b)). In addition, organization and governance models with clear performance metrics, a culture of continuous improvement, and new project management tools are advised to implement these cost reduction initiatives. For example, McKinsey (2011a) estimates that the U.K. infrastructure expenditure could be decreased by about 16% over the next 20 years by simplifying project governance, shortening timescales, advancing sub-contracting practices, and improving front-line staff supervision and work planning.

There is also significant potential to use the available infrastructure more efficiently. First, innovations can increase the technical maximum capacity of existing assets. For instance, next-generation air traffic control systems allow airport runway capacity to increase, and new grid technologies reduce the loss of electricity. Secondly, more efficient pricing schemes approximating marginal costs reduce excess demand (demand management) and result in more allocatively efficient production levels. For example, the proposal of the E.U. commission to introduce a market-based airport slot trading scheme and limiting airlines' grandfather rights would allow the system to handle 24 million more passengers a year by 2025.[23] Similarly, introducing cordon tolls in cities like London, Stockholm, and in Norway have eased congestion and increased ridership on public transit (Lauridsen (2011)). A roll-out of smart grids and smart metering technology would balance supply and demand of electricity more efficiently and decrease the costly peak-capacity requirements by shifting some demand off-peak.

But even if the above strategies to decrease costs and explore new revenue sources for infrastructure are successfully implemented, sufficient up-front finance still needs to be raised for new infrastructure investments. Even though the private investment market has continuously evolved, more efforts are needed to facilitate private finance. First, governments need to establish a stable and predictable political environment and a standardized legal PPP framework with independent regula-

[23]Source: ec.europa.eu/transport/air/airports/airports_en.htm. Retrieved on 5 December 2011.

tory institutions, transparent tendering processes, and a coherent regulatory design that balance operator attractiveness with state interest safeguarding. Moreover, governments should invest in adequate structuring, execution, and monitoring capabilities and pool knowledge in PPP expertise centers. Secondly, private investors need to develop a better understanding and more transparency on the characteristics of infrastructure investments in order to reduce the risks of an emerging asset class and to make profound investment decisions. For example, pension funds which have significant assets under management are interested in the asset class, but some are hesitating to invest due to a lack of experience with and transparency of this investment class. Hence, additional insights into the infrastructure investment characteristics may contribute to closing the looming infrastructure gap by attracting further investors.

2.4 Infrastructure delivery and financing models

2.4.1 Public

Infrastructure is traditionally delivered by the public sector, either directly by national, regional, and local governments or indirectly through government agencies and public corporations. These public sector entities typically prioritize projects and decide on their implementation, design and plan the facility and the service provision, finance and monitor the construction, and operate the asset. While construction and select operational tasks may be outsourced to the private sector, the asset ownership and the resulting financing need as well as the commercial responsibility and risk taking constitute the key characteristic of this delivery mode. Wagenvoort et al. (2010) estimate that about 40% of the infrastructure investments in the E.U. are financed publicly, though this varies strongly by sector with utilities and transport showing a significantly higher share than social infrastructure. In contrast, in emerging countries public finance still represents about 80% of the amount of infrastructure investments realized in the last 15 years (Estache and Fay

(2007)).[24] While in telecom and electricity generation 59% and 47% of developing countries have at least some private sector financing, the respective share for electricity distribution and water/sanitation are 36% and 35% (Estache and Goicoechea (2005b)).

Public infrastructure projects are typically funded by general taxes (e.g. income tax), user-specific taxes (e.g. gas tax), user fees and fares (e.g. tolls, parking charges), and indirect revenues (e.g. land value capture, ancillary revenue). Correspondingly, the original payers can be classified into taxpayers (which may include non-users), users, and indirect beneficiaries (Nakagawa et al. (1998)). While taxation is the mainstay of public infrastructure funding, the employed sources vary by country and sector. For telecom and airports a high share of funds is levied through direct user charges. In contrast, railways are largely funded by national taxes in France and Germany, whereas they are user funded in the U.S. and in Japan. Roads investments are typically recovered through a mix of user and general taxes (Nakagawa (1998)). The mechanisms how tax income is actually disbursed varies from discretionary allocations out of the general budget to dedicated accounts that appropriate funds for specific uses such as the U.S. Highway Trust Fund (McDaniel and Coley (2004)).

The upfront capital for the initial infrastructure construction is raised through either public debt or directly financed out of the national or local public sector budget. Around the world, public debt is typically issued through federal bonds. In addition, there are (sometimes tax-exempted) municipal bonds, e.g. in the U.S. and Canada, which are either designed as revenue or general obligation bonds. Revenue bonds are repaid by project cash flows, while the general obligation bonds are secured by the state/local government and may use taxes for debt service (Chan et al. (2009)). On the contrary, European countries also typically borrow through public and private agencies such as municipal banks via bank loans of long duration. Moreover, public development banks, such as the European Investment Bank (EIB),

[24] A previous estimate of Esty et al. (1999) asserts that 85% of the global infrastructure investment is provided by the public sector.

assume an important role in public infrastructure finance as they provide repayable grants and low-interest loans where market failures prevent private financing.[25]

2.4.2 Private and Public-Private Partnerships

Over the past decades private delivery and financing of infrastructure has increased at the expense of the traditional procurement model. In some countries such as France, Italy, and Portugal the private sector contributes more than 70% of total infrastructure finance (Wagenvoort et al. (2010)). As a result, the total accessible annual PPP investment market has grown to $200 billion globally.[26] But private involvement in infrastructure development is not a new phenomenon as many historic examples demonstrate. For example, water services were initially pioneered by private investors in the 16th century in the U.K. (NRC (2002)). Likewise, in the U.S. the turnpike roads of the early 19th century and the streetcar systems of the early 20th century were also privately operated, before they got turned over to the public sector (Jacobson and Tarr (1995), Center for Transit-Oriented Development (2008)). In modern times, a new wave of privatization was ushered in by Margaret Thatcher in the late 1970s and the early 1980s in the U.K. telecom and utilities sectors. Since then, other countries, most notably Japan and Australia as well as Western European and Latin American countries followed and infrastructure privatization has reached across all sectors.

Private involvement in infrastructure delivery can take different forms, ranging from privatization through PPP models[27] (e.g. BOO, BOT, DBFO, DBO) to pure service contracts (e.g. DB, DBB, management contracts). Depending on the degree of private responsibility and risk taking the following forms can be differentiated –

[25]Moreover, development banks provide sector-specific planning, design, risk management, and deal structuring knowledge and perform financial and project due diligence providing investment signals to other investors.

[26]Author's calculation using the Infrastructure Investor database as of 14 March 2012. The total market only includes tendered projects, i.e. it excludes investments of privatized corporations.

[27]Public-Private Partnerships constitute "a cooperative arrangement between the public and private sectors that involves the sharing of resources, risks, responsibilities, and rewards" often for a pre-defined time period (Kwak et al. (2009)).

ordered in decreasing private sector involvement and risk taking (United Nations (2009)):

- Privatization: The asset is sold to the private sector (e.g. in an IPO or trade-sale) for an indefinite time. The private sector is responsible for design, planning, construction, finance, and operations and assumes all related risks. The public sector only retains regulatory powers with regard to monopoly abuse and general legislation.
- Build-Own-Operate (BOO): The private sector provides the financing and construction of the project and usually owns and operates the asset in perpetuity, though the public sector may still retain certain responsibilities and risks in contrast to full privatization, e.g. facility planning and design.
- Build-Operate-Transfer (BOT), Design-Build-Finance-Operate (DBFO), Design-Build-Operate (DBO): For a given concession duration, a private entity takes the responsibility for the design, construction, financing, operation and maintenance of the project. In most cases, the ownership stays with the public sector over the whole project. After this time, the private partner transfers the asset (and possibly the ownership) back to the public authority.
- Lease, Affermage: The public sector designs, constructs, finances, and owns the infrastructure facility but leases it to a private sector entity for a certain time period during which the private sector assumes all operational risks.
- Design-Build (DB), Design-Bid-Build (DBB): The private sector is contracted to design and construct the infrastructure facility. Often lump-sum turnkey contracts are used where the private sector assumes all design and construction risk whereas in cost-plus arrangements the public sector retains most of these risks.
- Management contracts for operations and maintenance: The public authority outsources the operation and maintenance responsibilities of a publicly owned facility to the private sector.

The benefits of private participation in infrastructure delivery include the following arguments (Engel et al. (2011), World Bank (2004), Geltner and Moavenzadeh (1987)):

- Increasing expenditure and revenue efficiency: The private sector has stronger incentives to operate and construct efficiently under a comprehensive life-cycle perspective (e.g. proactive maintenance; new technologies; embedding of real options in design; access to finance, engineering, design, and legal talent; economies due to global scale) and to maximize revenue opportunities (e.g. minimize revenue leakage, optimize user pricing, develop ancillary business, optimize user quality through technology, process, and product innovations).
- Unbundling and reallocation of risk: If risks are allocated to the party that can identify and mitigate them because of informational, resource or incentive advantages, overall economic costs are reduced.
- Bridging a financing gap and speed of development: When investment requirements are high but the public sector faces fiscal constraints or other competing needs, private sector financing can alleviate investment delays. The private sector finances the required capital upfront and does not use pay-as-you-go financing. Hence, the macroeconomic benefits and positive externalities of infrastructure occur earlier.
- Immunization against political failure: White elephant projects are filtered out as private financiers conduct a thorough market test, which is particularly valuable in countries with weak social project evaluation. As user pricing is set free from political concerns, prices potentially remain closer to marginal cost.

But privatization also regularly raises public objection. First, private operators may not take positive and negative externalities as well as equity, environment, safety, and community aspects into account in their decision making as the public sector does. Secondly, private delivery implies a loss of public sector control and flexibility since the private sector is managing the project and executing the services for a long time horizon – which is of particular concern as interdependencies with other facilities in these network industries need to be coordinated. As initial contracts are often incomplete, costly renegotiations may be required to accommodate for changing conditions and requirements. Thirdly, if the public authority does not have the capacity to adequately arrange or regulate a PPP structure, the private sector may earn excess economic profits. Fourthly, private involvement causes significant transaction costs because of complex contract and project structures that require significant staff and consulting resources for both the private sector to evaluate projects and the public sector to monitor and regulate firms. Finally, the theoretical arguments for private sector efficiency and innovation need to be effective in practice and the relative cost of capital need to be assessed.[28]

In summary, there is no general consensus whether privatization or PPPs are more cost-efficient than public provision as the empirical evidence is slim (Small (2010)). While Infrastructure Partnerships Australia (2007) finds that PPPs are 31% more cost efficient (when measured from project inception) than traditional procurement, Blanc-Brude et al. (2009) find that European road PPPs are 24% more expensive to construct. A review of toll road projects in Norway does neither support the view that construction costs are significantly lower for PPP compared to traditional procurement projects (Lauridsen (2011)). In addition there are many examples of failed PPPs (e.g. Argentinean road concession, the Manila MRT2, and the London Jubilee Line Extension (Zegras (2006), KPMG (2010))) and privatizations (e.g. British Railways (Thompson (2004))). While privatization may yield significant economic benefits, an appropriate market design, regulatory structure, and continuing government involvement in the planning aspect are indispensable to

[28]While financing costs are often nominally 200-300 basis points higher for PPP projects relative to public finance (Yescombe (2007)), economic theory suggest that in an ideal world with full information and no transaction costs there is no premium (Grout (1997)). Public sector debt is based on average cost of capital and is subsidized by an implicit taxpayer guarantee. In contrast, private sector financing is project-specific and thus based on marginal costs, and is only supported by project revenues, hence the higher perceived capital costs for PPPs.

assure the long-term viability and alignment with public policy objectives and to account for public good issues, externalities, and monopolies. An additional concern that governments have to take into account is the impact on distributional equity as infrastructure services are a complementary input to social benefits such as education, health services, and employment opportunities (Serebrisky et al. (2009)). For example, the tolling of private highways is broadly regressive, while funding through general taxation is more proportional to income (Transportation Research Board (2011)). Policy instruments to remedy these adverse equity impacts include subsidies to reduce service prices, authorization of discounts and exemptions for low-income groups, and offering or improving alternative services.

While the public sector mainly relies on taxes for funding infrastructure investments, the private sector recovers investments through user charges, ancillary revenues, and possibly subsidies. Private operators try to extract the maximum producer rent by charging users based on marginal costs and their willingness to pay differentiated by customer group, time, and location, effectively applying Ramsey pricing. In addition, they often pursue innovative funding approaches and develop ancillary revenue sources. For example, some private airports derive more than 50% of revenues from retail, parking, advertising, and other airport-related services. Similarly, the Hong Kong Mass Transit Corporation generates around 30% of its revenues by capturing the value of residential and commercial real estate developments around its stations. Moreover, subsidies may contribute to funding private investments in situations where social exclusion from essential infrastructure services is an issue, where competing modes are not priced according to marginal costs, or where positive externalities prevail (e.g. the economies of scale and density of public transit due to reduced wait and walk times (Mohring (1972))).[29]

The private sector finances infrastructure projects either through equity, debt, or mezzanine capital. Equity for infrastructure projects is typically provided by

[29]For example, most empirical studies find that the high subsidies for urban rail – amounting to up to 89% of operating costs – are justified due to the economic benefits of relieving congestion and enhancing traveler welfare (Nelson et al. (2007), Parry and Small (2009)).

industrial project sponsors (e.g. construction and utility firms) and financial sponsors (e.g. private equity funds, pension funds). Equity may be provided by either cash or asset contributions such as land. Since equity bears the residual project risk the required return is comparatively high. To take advantage of the leverage effect and because of the large project volumes, debt is prevalent in private infrastructure financing. On average, 70% to 90% of infrastructure financing is through debt, though the typical leverage depends on the sector, the asset, and market conditions. The main debt instruments can be categorized into traditional bank loans, project bonds, and project finance loans. Traditional bank loans are mostly provided for a time horizon of 5 to 10 years, which may be insufficient as infrastructure often has payback periods of up to 30 years. Hence, loans are often used to bridge the initial construction phase, where a flexible draw-down structure is required. Depending on the project characteristics and market conditions infrastructure loans are typically priced between 30 and 300 basis points above the reference interest rate (e.g. Libor, Euribor). The new Basel III rules are expected to make long-term debt financing more costly for banks, hence a reduction of infrastructure bank loans is anticipated. Due to the large transaction volumes, banks often form syndicates in order to diversify credit risk and to be able to provide the required capital.[30] For infrastructure projects with long durations and high volume, bonds are an additional source of debt financing with typically lower interest rates than loans. However, they are inflexible with regard to refinancings and continuous capital draw downs. Bonds can be issued with terms of up to 50 years, with either fixed or variable interest coupons, and placed in the open or in the private market.[31] As the rating of many infrastructure bonds would be below the required investment threshold for large financiers such as pension funds and insurance firms, the creditworthiness is often enhanced through bond insurance or letters of credit by monoline insurers. Since

[30]The syndicate is led by the lead arranger, who structures and manages the transaction; or all banks act as arrangers at the same level in a club deal.

[31]Listed bonds may be subscribed by institutional and private investors whereas private placements are usually only offered to large institutional investors like pension funds. Listed bonds have the advantage of high transparency and daily liquidity, whilst private placements do not incur the costs for rating, placement, and listing.

the monoline market has dried up during the global financial crisis, the E.U. is currently drafting a new form of project bond credit enhancement supported by the EIB. In addition, governments and public development banks provide multiple financial support schemes, e.g. political risk insurance, to enhance infrastructure credit ratings (Dailami and Leipziger (1998)).[32] Another source of debt financing is project finance. Project finance debt – in contrast to traditional corporate finance loans – is issued as non-recourse debt, i.e. lenders can only resort to the cash flows generated by the project and have no rights to claim repayment from the sponsors in case of project default. Project finance is typically issued by a Special Purpose Vehicle which is legally independent from the sponsor with separate assets and liabilities and which expires after project completion (Esty et al. (1999)).

2.5 The infrastructure equity finance market

2.5.1 Investors, expectations, and activity

Since this thesis is concerned with the characteristics of private, equity-based infrastructure investments, this section gives a brief overview of the typical investors, their main expectations, and their investment activity. Pension funds are the foremost private source of infrastructure finance globally. They account for 41% of the limited partners in unlisted infrastructure funds worldwide (Preqin (2012a)).[33] Within this investor category, public pension plans represent 19%, private pension plans 16%, and superannuation schemes 6% of the total number of infrastructure investors. Other investors include insurance companies (8%), banks (7%), asset managers (7%), endowment plans (6%), and foundations (5%). Though Sovereign Wealth Funds (SWFs) only account for less than 5% of the total, 61% of all SWFs commit funds to the asset class (Preqin (2012b)). Correspondingly, the ranking of

[32] Issuers often charge users for these guarantees or require them to conduct cost-benefit analysis in order to assure a positive economic value contribution.

[33] Data on the investor composition of other infrastructure investment options such as listed stocks are not available.

the largest infrastructure investors in Table 2.3 is dominated by pension funds.

Table 2.3: Largest infrastructure investors

Investor	**Type**	**Location**	**Allocation ($ billion)**
OMERS	Public pension fund	Canada	15.1
CPP Investment Board	Public pension fund	Canada	9.2
Corporacion Andina de Fomento	Government agency	Venezuela	8.4
Ontario Teachers' Pension Plan	Public pension fund	Canada	7.9
APG - All Pensions Group	Asset manager	Netherlands	7.0
TIAA-CREF	Private pension fund	U.S.	6.5
Khazanah Nasional	Sovereign Wealth Fund	Malaysia	6.4
Industrial Development Bank of India	Investment bank	India	6.1
AustralianSuper	Superannuation scheme	Australia	5.1
CDP Capital - Private Equity Group	Asset manager	Canada	4.9

Note: The table only includes the largest investors in unlisted infrastructure funds.
Source: Preqin (2012a)

The motivation to invest in infrastructure is mostly based on the expectation to diversify investment portfolios, to generate stable returns, to achieve a real return above inflation, to earn yield-dominated returns, and to match assets to liability durations. These investment propositions are commonly ascribed to infrastructure assets based on the following reasoning (Colonial First State (2006a), Beeferman (2008)):[34]

- Portfolio diversification based on little market correlation: Due to the essential good and the natural monopoly characteristic, demand for infrastructure services is little correlated to business cycles and the stock market. Moreover, the price regulation of most infrastructure firms entails a buffering effect on cash flows.
- Stable returns based on low volatility: Due to the predictability of demand and low strategic and operational risks, infrastructure assets provide stable and regular cash flows. Demand is inelastic to price and quality changes due to the weak substitutability, low competitiveness, and high entry barriers (because of sunk investments and economies of scales).

[34] The first three investment propositions are analyzed empirically in chapters 5 and 7 of this thesis. Their theoretical foundation is discussed in detail in sections 3.1.1 and 3.3.1.

- Real returns and hedge against inflation: Due to strong pricing power, regulatory regimes that adjust prices to inflation, and the low operational cost exposure, infrastructure investments are considered to be hedged against inflation, i.e. provide stable real returns independent of inflation.
- Yield-dominated returns: Since infrastructure assets generate significant operational cash flows due to low variable costs, total shareholder returns tend to be dominated by dividend yields. Capital appreciation is of less significance since the growth options of infrastructure assets are often constrained.
- Asset-liability matching based on long durations: The technical life of infrastructure assets typically ranges from 30 to 70 years. Due to the high initial capital spending on construction, the paypack period and the economic life are similarly long. Thus, concessions for infrastructure typically range from 20 to 70 years.[35]

The return expectations for infrastructure investments typically range between 10% and 15%. In a Deloitte (2011) survey 12 funds report that they target an IRR of 12-14%, while 7 funds target 10-12%, and another 7 funds aim for more than 14%. But the return expectations are highly specific to the infrastructure sector. In sectors with limited potential for capital appreciation, such as existing toll roads and PPP projects, the expected IRRs range from 8% to 12%, followed by regulated utilities such as water, gas, and electricity distribution with 10% to 15%, and transportation assets such as rail, airports, ports, and greenfield toll roads with expected IRRs of 14% to 18%. Merchant power generation and communication networks feature the highest return expectations ranging from 15% to 25% (Weber (2009), JP Morgan Asset Management (2010)).

Most investors favor investments in regions with a stable political environment and a sufficient and steady supply of assets. As a consequence, Europe is the most important region, both in terms of market capitalization of listed infrastructure

[35]Port concessions typically range from 20 to 30 years, toll road concessions from 30 to 70 years, and airport concessions 30 to 50 years (Farrell (2010), Bousquet and Fayard (2001)).

firms ($2,192 billion) and the number of unlisted infrastructure funds and aggregate target capital (59 funds in the market seeking $41 billion of capital commitments). North America is the second most important investment market with an infrastructure market capitalization of $1,696 billion and 31 funds targeting $28 billion (Preqin (2012a)). Interest for investments in Asian countries is rising rapidly, with a market capitalization of $1,501 billion and 28 funds seeking a capital of $12 billion investing in this region. Though the preferences of individual investors may either favor greenfield or brownfield investments, the overall market is fairly split between both asset types. 69% percent of funds invest in greenfield projects, 81% in brownfield projects, and 54% in more established secondary stage opportunities (Preqin (2012a)).

Relative to other asset classes, infrastructure investing is still marginal. According to an investor survey by Russell Investments (2010), the average portfolio allocation to infrastructure amounts to 0.3%, though this is expected to rise to 1.4% within the next two to three years. Among investors that commit funds to the infrastructure asset class, the typical allocation is around 5% of assets under management. A Preqin (2012a) study shows that 7% of investors commit less than 1% of their capital, 44% between 1% and 5%, 29% between 5% and 10%, and 20% more than 10%.

Though some experts do not consider infrastructure an asset class[36] of its own, as it more looks "like a sub-asset class or sectors within the conventional finance vehicles such as listed equities, private equities, and bonds" (Inderst (2010)), about half of the infrastructure investors maintain specific allocation targets for the asset class (Preqin (2008)) – but these tend to be the larger and more experienced institutions. Investors that do not have a separate asset class allocation dedicated to infrastructure, invest in infrastructure mostly under their private equity allocation (28%), their real asset allocation including real estate (14%), or through a general alternatives allocation (8%).

[36]"An asset class is a set of assets that bear some fundamental economic similarities to each other, and that have characteristics that make them distinct from other assets that are not part of that class" (Greer (1997)).

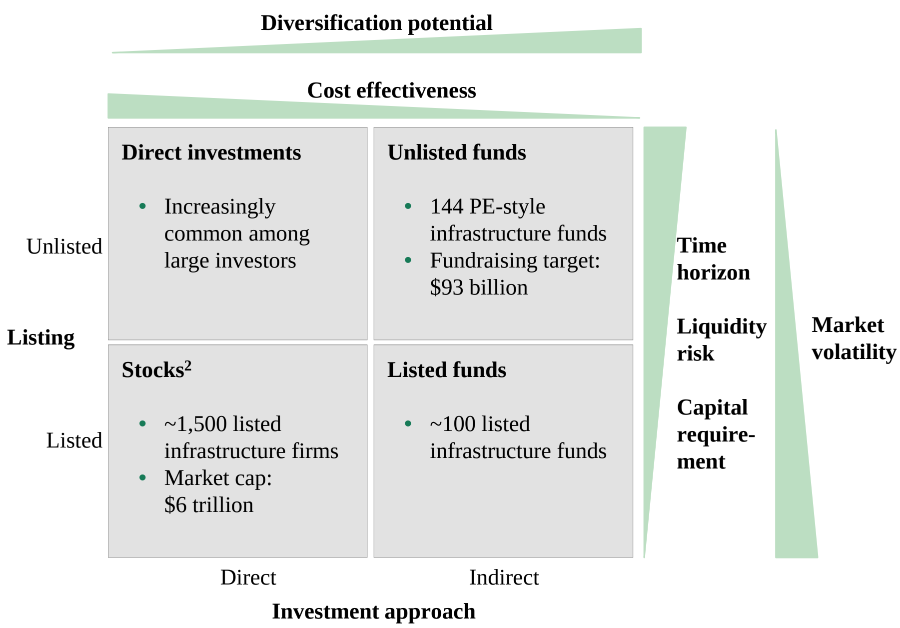
2.5.2 Investment options

Infrastructure investors have various options to gain exposure to the asset class:

- Direct investments
- Listed stocks
- Unlisted funds
- Listed funds

As illustrated in Figure 2.1, the investment options can be classified along two dimensions: investment approach (direct or indirect) and entity listing (listed or unlisted). While the investment approach determines the diversification potential and the cost-effectiveness, the listing of the entity defines the capital requirements, the investment time horizon, and the resulting liquidity risk.

Figure 2.1: Infrastructure investment options



Source: Author based on Bitsch et al. (2010) and Rothballer and Kaserer (2011)

Direct investments in unlisted infrastructure require significant amounts of capital due to the size of infrastructure projects and lock up the capital for a long time. Investors have to sustain material liquidity risk and often lack diversification. In contrast, listed infrastructure stocks provide investors the opportunity to gain infrastructure exposure with lower capital commitments. Investments are also sensible for shorter time horizons as listed securities provide higher liquidity and fungibility. However, investors face the stock market induced risk of volatile equity valuations. Indirect investments through funds are inherently more diversified as the fund manages a portfolio of infrastructure assets. They also enable exposure to unlisted infrastructure and specific asset types such as PPPs that are otherwise not accessible to small and medium sized investors. Similarly to listed infrastructure stocks, listed funds can be invested with lower capital commitments and permit shorter investment horizons. In contrast, unlisted funds are less exposed to the market velocity and provide smoothed returns. While direct investment approaches in unlisted or listed assets are cost-effective, fund investments entail significant fees with many funds following the “2-20” model of private equity funds.[37]

Most infrastructure investors (82%) prefer investments in unlisted funds as these support their objective of gaining long-term exposure at low volatility (Preqin (2012a)).[38] However, 68% of these funds have a life span of only 10 to 15 years, while merely 10% have defined maturities longer than 15 years and just 22% are perpetual funds (Deloitte (2011)). The largest unlisted fund managers include Macquarie, Global Infrastructure Partners, ArcLight, Alinda, and Goldman Sachs as listed in Table 2.4. The second most popular investment option is direct investing in publicly traded securities or through private placements, with 31% of investors favoring this approach. Another 8% prefers to invest through listed funds (Preqin

[37]“2-20” refers to a fee structure with a 2% management fee on the invested assets and a 20% carry on the excess return.

[38]Unlisted funds are predominantly structured as closed-end private equity type vehicles with General Partners (GP) as fund managers and Limited Partners (LP) providing the fund’s capital.

(2012a)).

Table 2.4: Largest infrastructure funds

Fund manager	Country	Funds	Capital ($ million)
Macquarie Infrastructure and Real Assets	Australia	19	26,050
Global Infrastructure Partners	U.S.	2	10,640
ArcLight Capital Partners	U.S.	5	10,118
Alinda Capital Partners	U.S.	3	10,097
GS Infrastructure Investment Group	U.S.	2	9,600
Highstar Capital	U.S.	4	8,206
Energy Capital Partners	U.S.	3	7,085
RREEF Infrastructure	U.K.	2	5,619
Brookfield Asset Management	Canada	4	4,824
Innisfree	U.K.	7	4,533

Note: The table only includes unlisted infrastructure funds. The number of funds and total capital refer to both in-the-market and raised funds.
Source: Preqin (2012a)

Infrastructure funds have particularly proliferated over the past years taking an increasing share of the infrastructure finance market (Hall (2006)). For example in the U.K., the ownership of privatized infrastructure utilities was initially focused on dispersed retail investors, but the emergence of private equity and infrastructure funds shifted and concentrated ownership over time (Helm and Tindall (2009)). Despite these successes, infrastructure funds were nevertheless hit during the financial crisis. Fund raising essentially ceased as many investors reduced their commitments as equity markets fell triggering a denominator effect, and as cheap debt to finance acquisitions became unavailable. Moreover, many limited partners began questioning some fund models due to their high leverage and opaque structures. In particular listed funds became unpopular with investors due to distributions out of capital, management fees decoupled from cash flows, aggressive leveraging of asset purchases, and corporate governance issues (RiskMetrics (2008), Lawrence and Stapledon (2008)). Another cause of concern are the high costs of both listed and unlisted fund structures, with 29% of investors seeing this as the major issue facing the infrastructure investment industry (Preqin (2010a)). Funds are reacting to this challenge by reducing asset management fees and carry, and creating more co-investment rights. Also the spectrum of funds and their specializations is proliferating with many funds focusing on specific sectors, assets, and special situations. Several funds are also expanding their skills from deal execution to optimizing asset performance (Deloitte (2011)).

As a consequence of the above elaborated issues, a couple of investors started to make their own direct infrastructure investments to circumvent costly and non-transparent fund structures. A group of 10 to 20 large institutional investors, mostly North American and European insurance firms and pension funds (e.g. Allianz) as well as Sovereign Wealth Funds (e.g. Abu Dhabi Investment Authority) are co-investing in infrastructure projects, in order to develop the capabilities to master such investments on their own (Clark et al. (2011)). However, direct investment is still limited to the lower risk end of the spectrum where there is less scope of operational improvement (Deloitte (2011)). Moreover, only a select number of investors realistically have the necessary operational resources and expertise to implement these investments in-house. Given all those barriers, only sophisticated investors that have significant assets under management and high percentage target allocations to infrastructure will be able to realize direct investments. The coming years will show whether "direct investors [...] appear ready to usher in the new era of infrastructure investing" (Clark et al. (2011)).

Chapter 3

Literature Review of Infrastructure Investment Characteristics

This chapter reviews the existing literature on the investment characteristics of infrastructure. It surveys economic theories and empirical studies on the investment risk profile, the relationship between regulation and risk, and the inflation hedging properties of infrastructure. Each section concludes with a summary of the previous research findings and the hypotheses that are tested empirically in chapters 5 through 7. These literature reviews are based on Rothballer and Kaserer (2011), Rothballer and Kaserer (2012a), and Rödel and Rothballer (2011), respectively.

3.1 Investment risk

3.1.1 Theory-based propositions

Since infrastructure is a relatively new alternative asset class, the academic body of literature on its investment risk profile is still constricted. Notwithstanding, several practitioner publications contain ex-ante claims on the characteristics of infrastructure investments based on economic theory (RREEF (2005), Colonial First State (2006a), Beeferman (2008), Rickards (2008), Inderst (2009), Sawant (2010b)). Across these publications, infrastructure is commonly considered as an asset class with low systematic and corporate risk. These hypotheses seem to have become conventional "Wall-Street" wisdom, as they are widely recited in the investment community (UBS (2009), Goldman Sachs (2010)), though empirical confirmations are lacking.

3.1.1.1 Systematic risk

The common arguments for the low correlation between infrastructure returns and the general stock market and the overall economy include the essential good characteristic, the natural monopoly situation, and the presence of price regulation. Infrastructure firms provide essential goods such as energy, communication, and mobility to people and corporations. The demand for these services is little correlated to disposable income or macroeconomic developments, as they are required to satisfy basic human needs or constitute basic inputs to the production process of any economic activity (Credit Suisse Asset Management (2010)). Most industries ranging from agriculture to services and manufacturing have a relatively fixed demand throughout the business cycle for energy, communication, and transportation to source, produce, and distribute their products and services. Moreover, demand is inelastic to price changes due to the natural monopoly situation of most infrastructure assets. The lack of direct competition is founded on the fact that infrastructure has high fixed costs and significant economies of scale, rendering a duplication of infrastructure (e.g. a parallel road) uneconomical. Indirect competition is also marginal as there are few substitutes or alternative technologies. In addition, the prevailing price regulation in most infrastructure sectors entails a buffering effect on the firm's cash flows (Peltzman (1976)). As regulators aim to maximize political support, they force exogenous cost or demand shocks to be shared between producers and consumers. Thus, the regulated prices will deviate from the competitive prices and favor producers in economic downturns and consumers during upswings.[1] As a consequence of the above three reasons, infrastructure firms are deemed to be immune to economic downturns and little exposed to economic cycles (Rickards (2008), UBS (2009), Inderst (2009)).

3.1.1.2 Corporate risk

Besides low market risk, it is claimed that infrastructure firms also exhibit stable, predictable and sustainable income streams due to little idiosyncratic risks (RREEF (2005), Inderst (2009), Sawant (2010b)). It is argued that this low idiosyncratic risk exposure is based on the low competitive pressure, little operational and strategic risks, and the employed price regulation in infrastructure industries. First, competition among infrastructure players is restricted due to large capital requirements imposing high entry barriers and due to large economies of scale implying natural (quasi-)monopolies (Goldman Sachs (2010), Kalmin and Hamieh (2007)). In addition, there are few or no substitutes for infrastructure services, thus demand reacts inelastically to price changes. Long innovation cycles, little exposure to R&D risks and the low operational complexity further contribute to this low idiosyncratic risk profile. As customer bases are often captive or locked-in through long-term supply contracts marketing risks are also relatively small. But even if cost risks materialize, the strong pricing power permits infrastructure players to pass those risks onto consumers (Martin (2010)). In addition, price regulation buffers infrastructure cash flows (Peltzman (1976)). Some regulatory regimes such as rate-of-return regulation even allow operators to pass operational cost risks onto customers. In an availability-based compensation framework, operators do not even have to sustain patronage risk (RREEF (2005)). In summary, the lower market and firm-specific risks of infrastructure firms are claimed to entail lower total corporate risk in comparison to other industries.

[1] Refer to section 3.2.1.1 for a detailed description of the Peltzman (1976) hypothesis.

3.1.2 Empirical evidence

3.1.2.1 Listed infrastructure

Empirical studies to confirm the above hypothesis on the systematic and corporate risk profile of infrastructure are scarce, as data availability constitutes a major obstacle (Inderst (2010)). In one of the first empirical analysis of infrastructure risk, RREEF (2006) constructs an industry size weighted portfolio based on 19 European listed infrastructure firms. The hypothetical infrastructure index returns 12% per year with a 13% volatility, sitting between European bonds and European equities in the risk-return spectrum.[2] The index exhibits a low correlation with cash, bonds, and real estate but its correlation with European equities (0.68) is higher than that for listed real estate (0.40), direct real estate (0.44) and government bonds (-0.13).

In a subsequent analysis using a larger sample, RREEF (2007) finds that the volatility of the UBS Infrastructure & Utilities Index stands at 18% exceeding fixed income and hedge funds, but being on par with public equities, public real estate, and private equity. Peng and Newell (2007) also use UBS infrastructure indices and confirm the high volatility (16%), surpassing the general stock market (11%), listed property (8%), and direct property (2%). Though the correlation with the stock market is low with a correlation coefficient of 0.21, sub-period analyses show that it has increased in recent years, suggesting declining diversification benefits. Colonial First State (2009) alludes to the fact that the high level of volatility is primarily driven by the first five years of the analyzed 10-year time series. They attribute the high volatility to the relative immaturity of the infrastructure sector, the high proportion of off-shore assets, and the high gearing levels. They also confirm the modest correlation between infrastructure and equities (correlation coefficient 0.51). In a study focusing on North and Latin American infrastructure, RREEF (2009) concludes that infrastructure is less exposed to economic downturns

[2] Though the index is designed to be representative for the infrastructure market by applying sector specific market size weightings, the low number of just 19 underlying companies including only one port and two airports, the presence of firms with suspiciously low volatilities (e.g. Autoroutes Paris-Rhin-Rhone with 5%), and strong internal diversification (e.g. E.ON, Enel, Suez) give rise to doubts about its representativeness.

as it has proven more resilient than other stocks and listed real estate during the financial crisis. In a study of 25 Hong Kong-listed infrastructure firms from 1995 to 2006, Newell et al. (2009) again find similar volatilities among infrastructure and other stocks.[3] The modest market correlation of infrastructure is again confirmed with a correlation coefficient of 0.6, which is also in line with Rickards (2008) and Sawant (2010b) who find equity market correlations in the range of 0.5 to 0.7 for various other infrastructure indices. When studying the cost of equity of 48 industries from 1963 to 1994, Fama and French (1997) find that telecommunication and utilities have the lowest market risk among all industries in both the CAPM and the three-factor model specification with beta values of 0.66 for both sectors. Alexander et al. (2000) find similarly low beta values for their sample of 71 transportation infrastructure firms. The results from most regulatory reviews regarding the determination of adequate capital costs also support this observation (e.g. Oxera (2009), Network Economics Consulting Group (2003), NERA (1999)). The only analysis on infrastructure project bonds by Sawant (2010a) finds that those offer low volatility, stable returns, and low correlation with equities.

3.1.2.2 Unlisted infrastructure

Colonial First State (2006b) is the first to analyze an unlisted infrastructure series using a self-constructed unweighted portfolio of five Australian infrastructure funds with varying inception dates in the ten years ending June 2006. Historical returns for the unlisted series outpace all sectors with the exception of listed infrastructure funds and commercial real estate, but the return volatility for unlisted infrastructure is the lowest among all analyzed assets, even lower than property. Unlisted infrastructure also shows strong portfolio diversification benefits as the correlation coefficients with equities (0.27) and all other asset classes are relatively low. Peng and Newell (2007) use the same unlisted funds as Colonial First State (2006b) and confirm the low volatility (6%), and the low market correlation (correlation coef-

[3] They also find more stability in the volatility of infrastructure in recent years, reflecting the growth and increasing maturity of these assets over the 12-year period.

ficients of 0.06). Finkenzeller and Dechant (2010) again analyze this dataset of unlisted and listed infrastructure data and find both excessive volatility and target semi-variance in comparison to equity. By applying a mean semi-variance optimization framework, they derive a considerable allocation target for infrastructure ranging from 7% to 30%, providing further evidence for the portfolio diversification benefits of infrastructure.

In a comprehensive study of 363 infrastructure and 11,223 conventional private equity transactions Bitsch et al. (2010) come up with mixed conclusions on the relative riskiness of unlisted infrastructure.[4] While they do not find any evidence supporting the hypothesis that infrastructure offers more stable cash flows, default frequencies are significantly lower for infrastructure investments.[5] In contrast to most other studies they find that infrastructure deals have a higher public equity market correlation than non-infrastructure – though being offset by the superior returns from infrastructure deals in comparisons to classical buyout deals. Like Buchner et al. (2008) they support the view that the risk of direct infrastructure investments is quite similar to that of traditional private equity buyout deals and does not show the often acclaimed bond-like features. In contrast, Preqin (2010b) concludes that infrastructure funds are less risky and more resilient than buyout, venture, and real estate funds when analyzing 72 unlisted infrastructure funds with vintage years between 1993 and 2007. The standard deviation of net IRRs for infrastructure across all years is 15% whereas it is 23% for buyout, 54% for venture, and 26% for real estate funds. Also, the median net IRR of infrastructure funds with vintage years 2006 and 2007 remained positive during the financial crisis while it turned negative for the other fund types. The statistical validity of these results is questionable as no significance tests are performed and the number of underlying infrastructure funds with vintage years in 2006 and 2007 remains unclear.

[4]Note, that the used sample is dominated by telecommunication which makes up 59% of the deals, followed by natural resources and energy with 25% of the deals.

[5]AMP Capital Investors (2010) also finds lower default frequencies for infrastructure in comparison to other types of equity investments.

3.1.2.3 Public-Private Partnerships

Sirtaine et al. (2005) evaluate the risks and returns from 34 Latin American Public-Private Partnership concessions in water, transport, telecom, and energy. Contrary to the general public perception, they find modest financial returns well below the required cost of equity, a high return volatility across concessions, sectors, and time as well as negative returns for many concessions, indicating that substantial risk is involved in these concessions.[6] Estache and Pinglo (2004) replicate this methodology for 120 electricity, water and sanitation, railway, and port concessions in 31 developing countries confirming that average returns to equity are lower than the cost of equity. Returns are found to be quite dispersed across sectors with some sectors exhibiting negative average returns and particularly high standard deviations of return to equity.

3.1.3 Summary and hypotheses

Despite these initial empirical studies, the overall evidence on the relative riskiness of infrastructure in comparison to other equities remains limited. Several studies indicate that both listed and unlisted infrastructure indeed have a modest market correlation, though equity correlations are mostly higher than for other asset classes such as real estate, bonds and hedge funds. In terms of total corporate risk the findings diverge. While several authors find that total corporate risk for infrastructure is on par with other industries, other authors find evidence that it is indeed lower.

However, some of the previous findings are questionable as many publications suffer from methodological shortcomings. Most publications rely on relatively short data series and a low number of cross-sectional observations. The scope of most studies is limited either in terms of geography and/or sector giving rise to doubts about their representativeness. Another shortcoming is the fact that many studies rely on infrastructure index data with usually strong utility weightings, therefore

[6] For example, the standard deviation of return on equity over the last 10 years is 15% for water, 6% for transport, 7% for telecom, and 8% for energy.

disguising the risk characteristics of other sectors. Another issue with index data is that they sometimes include companies that do not own or manage infrastructure assets.[7] Indices also do not allow a proper analysis of total company risk as diversification is differently pronounced in indices because of varying numbers of constituents. Lastly, many studies do not employ risk metrics for both total and market risk and lack the statistical robustness to provide conclusive insights into the risk characteristics of infrastructure.

Due to the shortcomings of the previous studies, I analyze both total and market risk of listed infrastructure in an integrated, econometrically sound approach that controls for confounding risk factors. A large, global sample across all infrastructure sectors is paramount to assure that the whole asset class is represented, but also to permit a de-averaged analysis of individual sector features. Based on the theoretical reasoning in section 3.1.1 the following hypotheses are tested in chapter 5:

H1.1: Listed infrastructure firms have less corporate risk than other public equities

H1.2: Listed infrastructure firms have less market risk than other public equities

3.2 Regulation and risk

3.2.1 Theories of regulation

This section surveys the theoretical literature on the relationship between regulation and systematic risk.[8] First, Peltzman (1976)'s theoretical model and its predication on the relationship between price regulation and market risk is introduced. This is followed by the theoretical arguments on the impact of the regulatory regime and

[7]For example, the UBS Global Infrastructure & Utilities Index which is largely utilized by previous empirical research includes firms that do not own or operate physical infrastructure assets, e.g. British Airways (RREEF (2006)). Another weakness of this index is that it does not include firms from several emerging markets, e.g. China. Other indices also contain companies that are not considered infrastructure assets, e.g. the INFRAX includes construction companies.

[8]This literature review is focused on the impact of price regulation. Other regulatory interventions such as quality of service or market structure/entry regulation are not considered.

regulatory independence on systematic risk.

3.2.1.1 The Peltzman model

In his economic theory of regulation, Stigler (1971) argues that regulation is a good demanded by interest groups and supplied by governments who aim at building and maintaining political support. Peltzman (1976) formalizes this idea in a model where selfish politicians seek to maximize their political majority $M = M(p, \pi)$ where p is the product's price paid by consumers, and π the profit retained by producers. The function M is assumed to be decreasing in p since consumers vote against higher prices ($M_p < 0$), and increasing in π as producers may use profits to influence voters ($M_\pi > 0$).[9] Politicians optimize their objective function M subject to the producers' profit $\pi = f(p, c)$, where c denotes costs and $f_p > 0$, $f_{pp} < 0$ and $f_c < 0$. This can be formulated as maximizing the Lagrangian $L = M(p, \pi) + \lambda(\pi - f(p, c))$ which yields the following optimal condition:

$$M_\pi = -\frac{M_p}{f_p} \tag{3.1}$$

In the political equilibrium the marginal political benefit of a dollar of profits (M_π) equals the marginal political benefit of a price cut ($-M_p$) that also costs a dollar of profits (f_p is the loss of profit per dollar price reduction). In other words, politicians trade-off producer interests (high profits, high prices) and consumer interests (high consumer rent, low prices) – represented as marginal vote gains or losses – in order to maximize political support. The equilibrium implies that neither a pure consumer protection policy nor a pure producer protection will be rational for regulators.[10] By accommodating the two opposing interests, the regulator sets prices between the monopoly (profit-maximizing) and the competitive (welfare-maximizing) price.

In case an exogenous cost or demand shock affects this political equilibrium,

[9] It is further assumed that political returns to lower prices and higher profits are diminishing ($M_{pp} < 0$, $M_{\pi\pi} < 0$).

[10] Except for the extreme cases where there is either no marginal consumer reluctance to increasing prices or no marginal producer support for increasing profits.

regulators will react and adjust the prescribed prices. Peltzman (1976) shows that any parametric shift dx in the cost function – representing a cost shock – will lead to the following change in prices:[11]

$$\frac{dp}{dx} = \frac{-\lambda f_{px} + f_x f_p M_{\pi\pi}}{-(M_{pp} - \lambda f_{pp}) - f_p^2 M_{\pi\pi}} \tag{3.2}$$

In this formulation the increase in price has distinct economic and political components. The first term of the denominator expresses the substitution effect similar to that of an unregulated firm, since a rise in marginal costs makes a higher price profitable. The second term, however, shows the peculiar reaction of the regulator: As overall wealth is smaller, he reacts by reducing his purchase of political support and thus does not force the entire adjustment on firms only, but requires the consumers to buffer some of the external shock. The above equation can be rewritten as the change of profits upon the cost shock:

$$\frac{d\pi}{dx} = \frac{f_x}{1 + f_p^2 \left(\frac{M_{\pi\pi}}{M_{pp} - \lambda f_{pp}}\right)} \tag{3.3}$$

From this formulation it becomes obvious that the profit change after a cost shock under regulation is smaller or equal to the change for an unregulated context which would be f_x.

The above conditions for optimality imply that the adjustment to an external shock is not entirely forced upon firms (or customers), but is dampened by requiring the other party to partially absorb the exogenous change. As a consequence, regulators tend to limit windfall producer profits and protect consumers during economic expansions, but restrain downside variability and benefit producers during depressions to ensure the firms' cost recovery and going concern. Hence, the existence of price regulation entails a buffering effect on the regulated firm's cash flows. To the extent that these cost and demand shocks are economy-wide this regulatory behavior results in lower systematic risk relative to an unregulated context.

[11] A similar result can be obtained when analyzing demand shocks.

3.2.1.2 Incentive vs. cost-based regulation

Besides the existence of price regulation, systematic risk is also influenced by the employed regulatory regime, i.e. the mechanism that is used by the regulator to prescribe maximum prices to the regulated firm. In principle, cost-based regimes (e.g. rate-of-return (RoR)) can be distinguished from incentive regimes (e.g. rate freeze, price cap, revenue cap, yardstick (Shleifer (1985))). Cost-based regulatory regimes compensate firms based on incurred costs and sunk investments. Prices are set to ensure that the return on assets does not exceed or undercut a pre-determined level. As prices are adapted to exogenous price and demand shocks, these risks are effectively borne by the consumers. This leads to the detriment of poor firm incentives for achieving operating and capital spending efficiencies as firms do not benefit from these efforts. In contrast, the central feature of incentive regulation is that prices (or revenues) are set ex-ante as a ceiling for a certain control period, usually by applying the RPI-X formula.[12] This mechanism replicates the risk and rewards inherent in competitive markets, and provides an incentive to pursue cost reductions as firms are rewarded by excess profits. On the contrary, firms bear the risks of unanticipated, adverse cost and demand developments increasing the firm's cost of capital and ultimately consumer prices, possibly undermining the benefits from the operational efficiency gains. In summary, this means that a firm subject to incentive regulation is exposed to the negative consequences of a demand or cost shock, whereas a firm subject to cost-based regulation is comparatively immune to such risks. To the extent that these risks co-move with the overall market the chosen regulatory mechanism affects systematic risk.

For an alternative derivation, consider the profit equation of a firm:

$$\pi = pq - (c^c + c^u)q - F \tag{3.4}$$

[12]RPI-X is the most widely used form of incentive regulation and is alternatively referred to as price cap regulation. RPI stands for the retail price index and X for the efficiency increase demanded by the regulator. Note, that prices are also set to give the firm a fair return on its assets, if it achieves the efficiency target.

where π is the firm's profit, p the price, q the output quantity, c^c the costs the producer can control, c^u the exogenous costs out of the control of the firm, and F the fixed costs. For firms in a competitive market all factors vary stochastically, resulting in a random profit function. Once regulation is introduced, certain elements of the profit function are considered and thus fixed by the regulator. The more factors are considered, the lower the risks for the firm and the cost reduction incentives. Under price cap regulation only prices are fixed by the regulator, while all other elements may vary and thus present a source of uncertainty for firms. Under perfect cost-based regulation without regulatory lags all factors in the profit function are considered by the regulator, i.e. firms will be compensated for any deviations, resulting in a deterministic profit. This means that a firm subject to incentive regulation is exposed to the consequences of a negative demand or cost shock, whereas a firm subject to cost-based regulation is mostly immune to such a risk. Expanding on Gaggero (2012)'s classification of regulatory regimes, Table 3.1 summarizes the profit determinants considered by various regulatory regimes and the associated level of producer incentives.

Table 3.1: Regulatory regimes and strength of cost reduction incentives

Regulatory regime	**Considered profit determinants**	**Strength of cost reduction incentives**
Rate freeze	p	High
Price cap	p	High
Revenue cap	p, q	Medium
Price cap with cost pass-through	p, c^u	Medium
Rate case moratorium	p, c^u	Medium
Rate-of-return	p, q, c^u, c^c	Low
Other cost-based regulation	p, q, c^u, c^c	Low

Source: Modified from Gaggero (2012)

3.2.1.3 Political vs. independent regulator

Besides price regulation and the regulatory regime, the type of the regulator, i.e. whether it is a politically entrenched or an independent institution, has an impact on systematic risk. Traditionally, most natural monopolies are directly regulated by governments or any of its agencies. Due to the time inconsistency between election cycles and the payback duration of infrastructure investments, a commitment (or hold-up) problem arises under this organizational form (Kydland and Prescott (1977)). Once capital-intense, long-lived, and irreversible infrastructure assets are erected, politicians may be tempted to disapprove sunk cost recovery and drive prices down to marginal costs, i.e. below long-run average costs. Ex-ante governments can neither credibly self-commit nor can current holders of public authority constrain the decisions of future elected politicians. Moreover, regulatory contracts are incomplete by nature, i.e. not all legal consequences of every possible future state can be specified, due to the complexity and the long time horizons of infrastructure investments. The necessity for frequent regulatory contract renegotiations as documented by Guasch et al. (2003) provides ample scope for regulatory opportunism.

Levy and Spiller (1994) argue that for regulation to be credible both the discretionary regulatory actions within the framework and any potential changes to the system itself need to be constrained, and effective enforcement mechanisms are to be in place. An independent regulatory function embedded in a stable legal environment provides such a credible signal of commitment that creeping ex-post expropriation will not occur and that sunk costs can be recouped. Alesina and Tabellini (2008) add that delegation to bureaucrats is preferable if time inconsistency and short-termism is an issue, or if vested interests have large stakes in the policy outcome, as it is the case for infrastructure assets. While for politically influenced regulation any change of government is associated with an adjustment of regulated prices and firm profits – different ruling political parties are characterized by distinct majority functions and differ in terms of their target voter groups, exposure and susceptibility to lobbying activities, and ideological preferences for producer/consumer protection – independent regulators serve a constant policy objective and consistently apply a "political average" objective function as the regulator stays in office across multiple election periods. As these agencies are free of political interference, arbitrary administrative decision-making is restrained, and they are less inclined to follow populist voices that could yield short-run gains for the ruling politicians.[13] As a consequence, regulations in terms of price, quality, investment, and market entry are perpetuated, and the probability of opportunistic adjustments is reduced.

3.2.2 Empirical evidence

3.2.2.1 Existence of price regulation

Peltzman (1976)'s buffering hypothesis is widely investigated empirically and most studies on infrastructure industries are supportive of its predication that price regulation buffers cash flows and reduces market risk. In a first crude analysis Peltzman (1976) shows that betas of railroads and utilities decreased after their respective regulation in 1887 and 1907, though changes are insignificant. Norton (1985)'s analysis of the equity and asset betas of U.S. electric utility companies between 1951 and 1975 also confirms the theory as systematic risk of firms under rate regulation is uniformly lower than for their unregulated peers. Fraser and Kannan (1990) reaffirm this finding for a larger and more diverse sample of U.S. infrastructure and financial firms over the period from 1976 to 1986 using market measures of systematic, unsystematic, and corporate risk. Re-using the sample of Norton (1985), Binder and Norton (1999) also find evidence consistent with the buffering hypothesis when investigating the relationship between regulation and asset betas while controlling for a multitude of other determinants of systematic risk.

Instead of comparing regulated with unregulated firms, several studies exploit policy changes and their impact on firm risk. An advantage of this approach is that the same firms can be observed over time and the potential bias from other risk factors is reduced. Chen and Sanger (1985) analyze the liberalization of the U.S. natural gas industry in 1978 and they find that decreasing regulation increases measures of shareholder risk and thus reverses the buffering effect as predicted by the theory of economic regulation. Chen and Merville (1986) confirm that the

[13] In addition, the establishment of autonomous regulatory agencies correlates with further advantages such as skilled professionals and a framework of rules that provides the flexibility to react to unexpected circumstances.

buffering effect was also reversed as AT&T went through the deregulation process. Nwaeze (2000) analyzes the three major policy changes in the U.S. electric utility industry (The Public Utility Regulatory Policies Act of 1978, The Energy Policy Act of 1992, The Open Access and Transmission Access Rules 1996) which were designed to lower entry barriers, to increase customer choice, and to move towards market-based output prices. The results reveal a significant increase in earnings variability and systematic risk as well as negative abnormal returns around the events, implicating a reversal of the buffering effect. Sidak and Ingraham (2003) provide further evidence of the buffering effect for the mandatory unbundling in the U.S. telecommunication industry. Their results demonstrate that the beta values of BellSouth, Verizon Communications, and SBC Communications increased due to this policy change towards a more competitive environment. Moreover, they document significant positive abnormal stock returns for regulatory announcements that the unbundling would be reversed. Buckland and Fraser (2001) demonstrate that a regulatory tightening also reduced systematic risk for twelve electric utility companies in the United Kingdom using a time-varying beta model. Some researchers also use indirect approaches to analyze the buffering hypothesis. Taggart (1985) finds that leverage among 46 U.S. electric utility companies has increased after state regulatory commissions were established during the time period from 1912 to 1922. He concludes that the economic environment of utilities became more stable due to regulation and companies were able to bear a proportionally larger amount of debt in their balance sheet – providing support for the buffering hypothesis.

On the contrary, some studies question the universal validity of the buffering hypothesis. Davidson et al. (1997)'s analysis of 48 U.S. electric utilities operating in different regulatory environments from 1976 to 1992 partially rejects Peltzman's buffering hypothesis. During periods of falling or relatively stable factor prices, they do not discern lower systematic risk for intensely regulated firms. They argue that during this time, pressure from market constituents on regulators is moderate as electricity prices do not change substantially. Hence, due to the lax regulation there is no noticeable impact on systematic risk relative to an unregulated context.

However, in times of increasing input factor prices, they support the buffering hypothesis, as regulators seem to be inclined towards stricter regulation. In addition, the only study using emerging market data, conducted by Barcelos and da Silveira Bueno (2010) for 67 Brazilian electricity, telecom, water utility, gas distribution, and road concession firms for the period from 1999 to 2009, finds that equity betas of regulated firms are not different (or even higher) from those of their unregulated peers when controlling for the time-varying nature of betas as well as equity and time-specific factors. In addition, they analyze the reaction of firms' market risk to specific regulatory changes, i.e. a new regulatory framework for the Brazilian electricity sector, the inception of a new telecommunications sector index, and the approval of new telecom interconnection rates. They find further evidence that the additional regulations do not reduce, but rather increase the regulated firms' betas, hence going in the opposite direction to the buffering hypothesis. Their finding implies that in Brazilian infrastructure sectors there is significant regulatory risk, i.e. uncertainty about the regulator's behavior and commitment, which is manifested in the frequent modifications of the regulatory framework by policymakers. The cost of regulatory risk is also reflected in the high consumer tariffs for infrastructure services relative to other countries.

Several empirical studies have analyzed the impact of regulation on market risk for other industries than infrastructure, including financial institutions, tobacco, airlines, and steel. For these industries the evidence on the buffering effect is less conclusive as several authors (Fraser and Kolari (1990), Allen and Wilhelm (1988), Lamdin (1999), and Lenway et al. (1990)) find no significant alterations of risk, whereas others including Hogan et al. (1980), Brooks et al. (1997), Mitchell and Mulherin (1988), and Davidson et al. (1984) find that shareholder risk is negatively related to the intensity of regulation. When analyzing the impact of the 1982 Depository Institutions Act, Fraser and Kolari (1990) find no significant changes in risk of savings and loan associations' common stock. Similarly, Allen and Wilhelm (1988)'s analysis of the passage of the Depository Institutions Deregulation and Monetary Control Act reveals no significant alteration in systematic risk in any of the investigated portfolios of financial firms. In contrast, Hogan et al. (1980) find that shareholder risk is negatively related to the intensity of regulation using data from Bank Holding Companies in Australia. Brooks et al. (1997) provide further evidence consistent with theory, as their analysis reveals that the U.S. depository bank deregulation has increased the level of risk and the instability of betas. When analyzing the advertising ban on the tobacco industry, corresponding to tighter regulation, Mitchell and Mulherin (1988) find abnormal returns to incumbent firms (implying lower systematic risk) as the ban effectively limits competition by reducing entry into the industry. However, Lamdin (1999) reexamines this effect in an alternative event study design, concluding that their result is at odds with the earlier study and the buffering hypothesis. Contrary to expectation, Lenway et al. (1990) find that steel firms' systematic risk increased upon the imposition of new trade restraints and systematic risk decreased after the protection from import competition was rescinded. Davidson et al. (1984)'s analysis of the Airline Deregulation Act supports the buffering theory as the deregulation has a negative effect on market capitalization, implying higher cost of capital. In summary, the evidence from non-infrastructure sectors is ambiguous whereas the studies using infrastructure data mostly support the buffering hypothesis. This may be caused by the fact that the overall exposure to regulation is less pronounced in these industries as prices and profits are not directly regulated, but only indirectly impacted by regulation.

3.2.2.2 Type of regulatory regime

Empirical studies comparing the relative impact of incentive and cost-based regulation on systematic risk are relatively scarce.[14] The relationship between the regulatory regime and systematic risk was first empirically analyzed by Alexander et al. (1996) in a descriptive study of regulated firms across 19 countries from 1990

[14]Notwithstanding, a larger body of literature demonstrates the positive effect that incentive regulation has on efficiency, which potentially is a consequence of the hypothesized risk transfer (Mathios and Rogers (1989), Resende (2000), Ai and Sappington (2002), Estache et al. (2003)).

until 1995. After clustering the regulatory regimes for each country and sector according to the strength of cost efficiency incentives (price cap and revenue cap are classified as high-powered, rate-of-return as low-powered, and discretionary systems as intermediate), they produce cross-country averages for the three types of regimes by sector as well as averages across sectors to yield a single figure for each type of regime. Both the sector-specific and the aggregated results support the hypothesis that high-powered incentives imply higher market risk in comparison to low-powered regimes (high-powered: 0.71; intermediate: 0.60; low-powered: 0.32). However, the authors conclude that "[...] the observed difference in beta values may be due to a number of other factors and could, therefore, have little or nothing to do with alternative regulatory systems". Indeed, the analysis does not account for the sample heterogeneity in terms of firm size, stock liquidity, political and institutional environment, diversity of operations and business models, industry structure and product market competition, non-utility activities, geographical composition, and ownership. Moreover, the used market indices vary with regard to their composition and calculation methodologies, possibly rendering the beta estimates incomparable. In a follow-up study, Alexander et al. (2000) replicate the same methodology for a sample of 71 transportation firms across 15 countries for the five years until 1998. They corroborate the finding that asset betas are positively related to the degree of efficiency incentives for airports, buses, rail, and toll roads, though statistical tests are missing as in the previous study. However, the initial hypothesis is not valid for rail which is attributed to the exposure to inter-modal competition, low switching costs, and a higher dependence on macroeconomic factors.

Grout and Zalewska (2006) analyze the – finally abandoned – proposal of the U.K. government in the late 1990s to switch from a price cap to a profit-sharing regime[15] for all regulated firms in the telecom, water, electricity, and airport sectors. During the 25 months when the plan was believed to be implemented, they find that market risk for both the single-factor and the Fama-French three-factor models

[15]Profit-sharing is a hybrid form of regulation that contains elements of both rate-of-return and price cap regulation. Under profit-sharing the firm's profits and losses are explicitly shared with consumers as defined by some pre-specified rule.

is significantly reduced for the analyzed 15 firms relative to a control group of U.S. regulated companies. Their findings are robust for various time periods, for both the portfolio and the individual firm level, and for different estimation techniques. Consistent with theory, their results confirm the lower risk exposure of regimes with less efficiency incentives, such as profit-sharing.

Gaggero (2007) analyzes the impact of the regulatory regime on market risk for a sample of 93 regulated companies in English-speaking countries for the years from 1995 to 2004. He applies a panel data regression explicitly controlling for liquidity, leverage, efficiency, profitability, size, growth, payout, market, sector, year, and country. In contrast to previous research, he finds no significant difference between low and high incentive schemes for various different model specifications. Gaggero (2012) extends his initial sample by 77 firms from non-English-speaking countries yielding a global panel of 170 firms over the same ten years. He applies a similar methodological approach and his results reinforce his previous observation, though for a more heterogeneous and larger sample: Regulation characterized by high incentives does not imply more systematic risk for shareholders. He attributes his unexpected finding to a sophisticated diversification behavior of regulated firms, a possibly higher level of development of financial markets relative to Alexander et al. (1996)'s study, and to regulatory capture. He reasons that firms subject to incentive regulation may neutralize the adverse effect of cost reduction risks through active regulatory lobbying resulting in a capture of the regulator. Depending on their bargaining power and the benevolence of the regulator, firms might be able to impose cost risks onto consumers instead of bearing them on their balance sheets.

Two further studies analyze the impact of fuel-adjustment clauses (FAC) for electric utilities. FACs are used to reduce regulatory lag under high fuel price volatility by allowing regulated utilities to adjust the price of electricity whenever the fuel price deviates from a certain base. FACs correspond to a cost-based regulatory system as firms pass-through fuel price risks to consumers.[16] Consistent with

[16]Note, that FACs are independent of how other cost components are regulated. FACs can be implemented under both incentive and RoR regulation.

theory, Clarke (1980) finds that the use of FACs in 39 large U.S. electric utilities between 1965 and 1974 decreases the systematic risk of firms by approximately 10 percent. The decline in cost of equity is significantly greater for firms with a strong reliance on oil and gas as fuel source. However, Golec (1990)'s study of 79 U.S. electric utilities over the years from 1969 till 1983 suggests that FACs have a statistically insignificant effect on market risk.

3.2.2.3 Independence of the regulatory authority

To the best of my knowledge, no empirical study has yet directly investigated the relationship between the independence of the regulatory authority and systematic risk. Notwithstanding, the important role that sector institutions play in success and failure of infrastructure reforms is widely documented (Jamasb (2005)). The literature on monetary policy, where a similar time-inconsistency problem prevails, also stresses the relevance of independent central banks in addressing this problem (Barro and Gordon (1983), Rogoff (1985)). In addition, some preliminary insight into the relationship between the type of regulator and market risk can be derived from studies analyzing the effect of regulatory independence on other regulatory outcomes such as firm value, investments, contract renegotiations, and expropriations. With respect to the earlier, Bortolotti et al. (2011) find that independent regulation positively affects the market value of regulated firms, possibly implying lower market risk and thus lower cost of capital. Several studies also show that independent regulators entail increased levels of investment, which may also be caused by lower cost of capital. Gutiérrez (2003) shows that regulatory independence has a positive impact on telecom companies' investment in Latin America and the Caribbean, while Cambini and Rondi (2011) provide the same evidence for regulated European infrastructure firms. Égert (2009)'s analysis of country-level investments in infrastructure shows that regulatory independence fosters investments in the context of incentive regulation whereas regulation by bureaucrats does not entail this positive effect. Wallsten (2001) finds that telecom privatization in 30 African and Latin American countries being accompanied by an independent regulator is positively correlated with performance metrics such as the number of mainlines, payphones, and connection capacity, whereas privatization alone is associated with less benefits. Kirkpatrick et al. (2006) provide evidence that foreign direct investments in infrastructure respond positively to an effective domestic regulatory framework with independent regulatory institutions. Finally, the literature documents the positive effect that independent regulators have on contract renegotiations and expropriations. Guasch et al. (2007) show that independent regulators reduce the probability of government-led concession contract renegotiations – which implies lower systematic risk if renegotiations are linked to economic fluctuations and shocks. Bergara et al. (1998) and Stern and Cubbin (2005) point out the importance of a well-defined and credible political and legal environment as well as an adequately resourced and independent regulator in the electricity sector as it lowers the risk of expropriation.

3.2.3 Summary and hypotheses

Peltzman (1976)'s buffering hypothesis that price regulation reduces market risk and the cost of capital of a regulated firm is commonly accepted (Grayburn et al. (2002)), since empirical studies are mostly supportive (Norton (1985), Chen and Sanger (1985), Fraser and Kannan (1990), Binder and Norton (1999), Nwaeze (2000), Buckland and Fraser (2001), Sidak and Ingraham (2003)). Just a few researchers challenge the theory in the peculiar circumstances of falling and stable factor prices and in an emerging market context (Davidson et al. (1997), Barcelos and da Silveira Bueno (2010)). I aim to reexamine this hypothesis using recent data, as previous studies mostly rely on pre-1990 data, when infrastructure industries were highly regulated with possibly different risk properties. In addition, I aim to extend the empirical evidence to a global, cross-sectoral sample that is not limited to the countries (U.S., U.K.) and sectors (electricity, telecom) that previous studies focused on. The following hypothesis consistent with the Peltzman (1976) theory is tested empirically in chapter 6:

H2.1: Price regulation reduces market risk

Though regulatory theory suggests that high-powered incentive regimes imply higher systematic risk than those with less incentives, the previous empirical evidence does not unambiguously support this hypothesis. Whilst earlier research (Alexander et al. (1996), Alexander et al. (2000), Grout and Zalewska (2006)) confirm the theory, later panel regressions that control for other risk factors (Gaggero (2007), Gaggero (2012)) contradict the hypothesis. This motivates the need to investigate the following hypothesis with a large sample and an econometrically sound methodology controlling for a variety of confounding factors including other regulatory variables:

H2.2: Incentive regulation increases market risk relative to cost-based regulation

Regulatory theory suggests that independent regulators solve the commitment (or hold-up) problem that arises because of the time-inconsistency between the political cycles and the payback periods of infrastructure investments (Kydland and Prescott (1977)). Independent regulators minimize political interference and opportunism as they follow a stable policy objective independent of the ruling party using an independent budget and staff without competing political interests. This view is supported by several empirical studies that highlight the benefits of independent regulators with regard to investments, contract renegotiations, and expropriations. However, the potential benefits of regulatory independence with regard to systematic risk have not yet been investigated empirically. In addition to H2.1 and H2.2, I analyze the following hypothesis in chapter 6:

H2.3: Regulatory independence reduces market risk

3.3 Inflation hedging

3.3.1 Theory-based propositions

Several authors argue that investments in infrastructure are protected against inflation (RREEF (2005), Colonial First State (2006b), Orr (2007), Williams (2007), Rickards (2008), UBS (2009), Goldman Sachs (2010)). Their theoretically motivated claims are based on both cost-based arguments such as the real asset characteristic and the low input price exposure as well as on revenue-based arguments including high pricing power and the prevailing regulatory regimes.

3.3.1.1 Cost exposure

First, infrastructure is a tangible real asset like real estate and other equities. In an inflationary environment the replacement costs of real assets increase, hence protecting the value of past investments (RREEF (2007)). Secondly, infrastructure firms have a low share of operating costs. Their cost structure is dominated by interest expenses and depreciation charges caused by the capital intensive initial construction which are locked-in at historical prices. Other cost items that are exposed to inflationary tendencies such as salaries, commodity inputs, and maintenance only make up a relatively small share in the overall cost structure. Hence, infrastructure is generally little exposed to inflation from a cost point of view (Martin (2010)).

3.3.1.2 Revenue adaptability

Many infrastructure firms operate as (quasi-)monopolies, enabling them to pass inflationary price increases onto consumers due to their pricing power. As the price sensitivity of consumers for infrastructure services is low – because infrastructure services constitute an essential good and usually have neither substitutes nor direct competition – price increases do not entail a significant decrease in volumes, effectively linking revenues to inflation (RREEF (2005)). In addition, it is argued that some regulatory regimes such as incentive regulation embed a natural inflationary hedge (Rickards (2008)). Under most incentive regulation schemes prices are adjusted by RPI-X formulas on an annual basis, i.e. the allowed price increase equals the increase of the retail-price-index minus a required efficiency gain. Thus, prices and possibly revenues are directly linked to inflation. Similarly, most concessions governing infrastructure assets, e.g. toll roads, permit inflation-linked rent escalations (Colonial First State (2009)).

3.3.2 Empirical evidence

3.3.2.1 Infrastructure-specific studies

The above arguments are usually put forward to justify the ex-ante inflation hedging properties of infrastructure, but the empirical literature investigating this hypothesis is limited. In one of the first analysis on this research question, Peng and Newell (2007) surprisingly find negative, yet insignificant, correlations between Australian inflation and nominal returns for both listed and unlisted infrastructure over the time period from 1995 to 2006.[17] For one five year sub-period they even document a significantly negative correlation of listed infrastructure with inflation. In contrast, the correlation between inflation and the general stock market is less negative, and even positive for property, though none of the coefficients is significant for the full period. In summary, their findings oppose the wide-spread belief that infrastructure has superior hedging features than equities. However, the results are mostly insignificant, the analyzed time series short, and limited to a single country.

In contrast, Sawant (2010b) finds a positive relationship between the U.S. CPI and the nominal returns of three international infrastructure indices[18]. The infrastructure coefficients range between 0.09 and 0.11, being slightly higher than the correlation of the S&P500 standing at 0.05. In addition to the difference being statistically insignificant, this finding is questionable as the analyzed infrastructure indices include a significant proportion of international firms that naturally hedge U.S. inflation better than the U.S.-based S&P500 firms due to exchange rate moderation effects.

Instead of using returns of listed firms, Bitsch et al. (2010) compare the inflation hedging characteristics of 363 infrastructure and 11,223 non-infrastructure private equity like transactions. They find a positive relationship between inflation and the nominal internal rate of return for infrastructure investments, and a negative

[17] They use the international UBS infrastructure index and an unweighted portfolio of five unlisted Australian funds as proxies for listed and unlisted infrastructure, respectively.

[18] UBS Global Infrastructure & Utilities Index; Macquarie Global Infrastructure Index; CSFB Emerging Markets Infrastructure Index.

one for non-infrastructure. Despite the indication of a superior hedging quality of infrastructure, their evidence does not allow a definite conclusion since neither coefficient is statistically significant. Moreover, the validity of their findings is limited as German inflation data are used for all European deals prior to 1990 and U.S. inflation data are used for firms from all non-European countries across all time periods. The sample also includes a high share of Oil and Gas investments, which are not commonly considered as infrastructure, but hedge well against inflation due to their positive oil price exposure.

While the previously discussed studies analyze shareholder returns, Armann and Weisdorf (2008) revert to an analysis of annual cash flows (proxied by EBITDA) of U.S. regulated infrastructure assets and concessions over the time period from 1986 till 2005. They find a correlation coefficient of 0.35 between the nominal growth of infrastructure cash flows and inflation, indicating a comparatively strong inflation hedge, though significance tests are not carried out. Using the same approach with mature infrastructure assets in the U.S. and the E.U., JP Morgan Asset Management (2010) finds that cash flows grow steadily in the long run, at a rate above inflation regardless of the global economic environment. They conclude that infrastructure indeed is a good inflation hedge, but the lack of a statistically robust methodology raises doubts about the validity of this finding.

3.3.2.2 Comparative asset class studies

In addition, several publications investigate the inflation hedging features of equities across industry sectors. The used industry segmentations typically include utilities, whereas other infrastructure sectors such as telecommunication and transport are missing. Boudoukh et al. (1994) find that annual nominal stock returns from non-cyclical U.S. industries, including utilities, tend to co-vary positively with expected inflation, while they find the reverse for cyclical industries for the time period from 1953 till 1990. However, utilities (and other cyclical industries) appear to be quite negatively sensitive to unexpected inflation. Pilotte (2003) finds that expected inflation betas for total nominal returns to industry portfolios are similar in magnitude to those reported by Boudoukh et al. (1994) when using U.S. data from 1953 to 1997. He confirms the relative advantage of utilities as the beta with regard to expected inflation is 0.48, being within two standard errors of 1.0 and the third largest among all analyzed 12 industries. Van Antwerpen (2010) replicates this approach for a larger time series from 1928 till 2008, and provides various robustness checks across time, return index calculation methods, and data frequency. Again, utilities are among the better performing industries, though the results are mostly insignificant. Oil and Petroleum as well as Mining and Minerals turn out to be the best industries to hedge inflation. Luintel and Paudyal (2006) use co-integration based tests for U.K. data from 1955 till 1997 and find positive hedging characteristics for stocks overall and for almost all industries including utilities. However, their analysis provides no evidence for the superior hedging features of utilities relative to equity. Martin (2010) uses nominal utility return data from 1930 till 2008 and concludes that both hedged and unhedged utility returns are essentially uncorrelated with changes in U.S. inflation across most analyzed time periods.

3.3.3 Summary and hypotheses

The previous empirical findings on the inflation hedging characteristics of infrastructure diverge and do not present conclusive evidence. While some studies find an indication that infrastructure is an enhanced inflation hedge relative to equities (Armann and Weisdorf (2008), Bitsch et al. (2010)), others cannot find any support for this hypothesis (Peng and Newell (2007), Luintel and Paudyal (2006), Boudoukh et al. (1994)). Yet, most studies lack the statistical significance to derive any valid conclusion. This is exacerbated by the fact that most existing infrastructure specific studies use limited datasets and lack robust methodologies. Most studies rely on short time series of around 10 to 15 years, mix domestic and international assets, are limited to single currencies, and use small cross-sections of infrastructure data. These data issues are a direct consequence of the use of publicly available infrastructure indices in the previous studies, since these only cover the time period back to 1995. Any empirical evidence based on these indices is prone to biases as the 1990s and 2000s recorded historically low inflation rates. In addition, only few infrastructure indices are available on a country level, and most mix domestic and international infrastructure assets in one index. As a result, the inflation hedging quality of infrastructure are overstated due to pure exchange rate moderation effects if compared against domestic equity indices. Moreover, most studies are limited to single currencies and use small cross-sections of infrastructure data. None of the studies uses a regression approach, let alone controls for unexpected inflation or a robust treatment of the time-series properties of inflation data. Instead, most studies rely on simple bivariate correlations. In chapter 7, the following hypothesis on the inflation hedging properties of infrastructure is examined using a large dataset and employing a robust regression methodology:

H3.1: Listed infrastructure hedges inflation better than other public equities

Chapter 4

Sample and Data

This chapter introduces the samples and data used in the empirical analyses in chapters 5 through 7. First, I explain the firm identification and selection procedure for the infrastructure and the reference sample and analyze their constitution with regard to industry, region, country, and firm size. Finally, the firm- and country-level datatypes and their sources are described.

4.1 Infrastructure firm sample

4.1.1 The use of listed firms

The empirical analyses in this thesis are based on listed infrastructure firms. Therefore, a brief summary of the advantages and detriments of using listed firms instead of other equity instruments such as unlisted direct investments and unlisted/listed funds is expedient. The primary advantage of analyzing listed infrastructure firms is the fact that there are continuously available market prices which are difficult to observe for unlisted assets. Moreover, financial reporting standards assure the availability of high quality accounting and other firm-specific data. Hence, individual firm characteristics such as sector, region, size, leverage, profitability, asset intensity, and regulation can be directly analyzed. The public information on the business model also enables a better categorization of firms as infrastructure and non-infrastructure. In addition, the analysis of individual infrastructure firms instead of fund portfolios permits insights into the idiosyncratic risk exposure. But listed firms also suffer from a potential critique. Listed infrastructure stocks are exposed to the same market trends and market induced volatility as the general equity market, which may blur their risk characteristics. This critique presumes that stock markets do not differentiate between individual firms' performance fundamentals and implies a breakdown of the efficient market hypothesis. However, empirical studies show that stock markets are in fact semi-efficient (Fama (1998)), i.e. they correctly process and price publicly available information. Hence, listed firms are well suited to evaluate the riskiness of infrastructure *relative* to other industries since both the infrastructure and the reference samples used in this thesis consist of publicly-traded assets with the same exposure to market volatility. This is despite the fact that many infrastructure investors prefer unlisted investments to avoid the – in *absolute* terms – high volatility. Unlisted infrastructure has lower volatility and market correlation than listed infrastructure as appraisal-based valuations smooth out the market-driven volatility. But to allow for a fair comparison of listed and unlisted risk metrics, a de-smoothing procedure needs to be applied to the unlisted returns (Geltner (1993)). For example, Pagliari et al. (2005) show that the volatilities of private and public real estate are essentially the same after correcting for the smoothing bias. The above considerations should be taken into account if the empirical results of this thesis are compared against other analyses that are based on unlisted infrastructure returns.

It should also be kept in mind that this thesis relies on an analysis of infrastructure firms and not on individual assets. While assets evolve through a typical life-cycle involving construction, operations, maintenance, rehabilitation, and decommissioning, firms continuously invest in new assets and therefore constitute a bundle of assets along the life cycle. The risk characteristics of expanding firms are hence similar to greenfield assets, whereas firms with a stable portfolio are more similar to brownfield assets. Firms may also be active in a number of adjacent or diversified businesses diluting the risk characteristics of the underlying infrastructure asset. In addition, the financial policies of firms with regard to financing, cash flow usage, and capital investments may also distort the pure risk characteristics of an infrastructure asset.

4.1.2 Identification of firms

First, I determine all Standard Industrial Classification (SIC) and Global Industry Classification Standard (GICS) industry codes that relate to any of the sectors of economic infrastructure mentioned in the definition in section 2.1: Telecommunication (fixed-line, mobile, satellite, cable), transport (ports, airports, pipelines, railways, highways), and utilities (generation, transmission and distribution of electricity, gas and water).[1] The resulting list of industry codes is displayed in the Tables 4.1 and 4.2, and the corresponding industry code definitions are provided in the Tables 8.1, 8.2, 8.3, and 8.4 in the appendix. The collection of industry codes is intentionally broad in order to reduce Type I errors of not including select infrastructure firms in the final sample.

Next, Thomson Worldscope (TWS) is used to retrieve all active and inactive publicly listed companies (excluding American Depositary Receipts[2]) that carry any of these codes as their primary SIC or GICS code. All firms complying with these selection criteria were downloaded on 28 January 2010. This partially redundant search procedure employing both SIC and GICS codes is warranted to reliably identify all listed infrastructure firms and reduce Type I errors. Type I errors may still occur if listed infrastructure firms are either not recorded on TWS or if none

[1]Other classification schemes such as the North American Industry Classification Standard (NAICS), the Industry Classification Benchmark (ICB), or the Nomenclature of economic activities (NACE) are less suited for this purpose. They are either insufficiently detailed or not implemented in Thomson Worldscope.

[2]American Depositary Receipts are negotiable certificates that are traded on U.S. exchanges representing ownership in a specified number of foreign shares. They are excluded from the sample as suggested by Ince and Porter (2006), so that the underlying foreign company is not represented in the sample twice (through the home country and the ADR listing).

of the identified SIC or GICS codes is assigned.[3] After eliminating duplicates that originated from this combined search approach, 3,535 companies are identified. As for some of these companies – especially for inactive companies – TWS does not contain any further data records, the firm list is reduced to 3,298. As recommended by Peng and Newell (2007), this approach covers all infrastructure firms globally in order to address the limitation of previous research that is largely focused on single countries. By definition, it represents the total investable asset space for listed infrastructure equities. If the relative number of listed companies by sector and country also proxies the respective progress of privatization, the sample is also a good representation of the entire infrastructure asset class (e.g. including PPP, direct infrastructure investments).

4.1.3 Exclusion of non-infrastructure firms

The long-list of companies generated by the SIC and GICS based search procedure cannot be readily used as infrastructure sample. Type II errors, i.e. if the given firm is not infrastructure even though the industry code classification suggests that, need to be addressed by screening each firm individually for the defining infrastructure characteristics. The definition of most SIC and GICS industry definitions include a large variety of economic activities along the respective industry value chain. These classifications assume a horizontal industry perspective and effectively combine companies of different vertical value chain steps into one industry code. Thus, in many instances they do not differentiate between infrastructure network providers (layers 1 to 3 in the Knieps (2007) model), network service operators (layer 4), and ancillary service and product suppliers (layer 5). For example, the SIC code 4581 "Airports, flying fields, and airport terminal services" does not only include "establishments primarily engaged in operating and maintaining air-

[3]This risk is mitigated by the fact that TWS is one of the most comprehensive databases of listed firms worldwide containing 60,000 entities (Source: www.tfsd.com/marketing/banker_r2/T1B_factsheet.pdf. Retrieved on 20 February 2012.

Table 4.1: Infrastructure-related SIC codes

SIC code	SIC name
4812	Radiotelephone communications
4813	Telephone communications, except radiotelephone
4822	Telegraph and other message communications
4832	Radio broadcasting stations
4833	Television broadcasting stations
4841	Cable and other pay television services
4899	Communications services, not elsewhere classified
4011	Railroads, line-haul operating
4013	Railroad switching and terminal establishments
4111	Local and suburban transit
4119	Local passenger transportation, not elsewhere classified
4173	Terminal and service facilities for motor vehicle passenger transportation
4231	Terminal and joint terminal maintenance facilities for motor freight transportation
4491	Marine cargo handling
4493	Marinas
4581	Airports, flying fields, and airport terminal services
4612	Crude petroleum pipelines
4613	Refined petroleum pipelines
4619	Pipelines, not elsewhere classified
4785	Fixed facilities and inspection and weighing services for motor vehicle transportation
5171	Petroleum bulk stations and terminals
4911	Electric services
4922	Natural gas transmission
4923	Natural gas transmission and distribution
4924	Natural gas distribution
4925	Mixed, manufactured, or liquefied petroleum gas production and/or distribution
4931	Electric and other services combined
4932	Gas and other services combined
4939	Combination utilities, not elsewhere classified
4941	Water supply
4952	Sewerage systems
4961	Steam and air-conditioning supply
4971	Irrigation systems

Source: Rothballer and Kaserer (2011)

Table 4.2: Infrastructure-related GICS codes

GICS code	GICS name
50101010	Alternative carriers
50101020	Integrated telecommunications services
50102010	Wireless telecommunications services
25401025	Cable and satellite
20304010	Railroads
20305010	Airport services
20305020	Highways & railtracks
20305030	Marine ports & services
10102040	Oil & gas storage & transportation
55101010	Electric utilities
55102010	Gas utilities
55103010	Multi-utilities
55104010	Water utilities
55105010	Independent power producers & energy traders

Source: Rothballer and Kaserer (2011)

ports and flying fields" but also companies "servicing, repairing, maintaining, and storing aircraft; and [...] furnishing coordinated handling services for airfreight or passengers". While many airports provide both types of services in an integrated business model (e.g. Fraport), there are several firms on the long list that fall into this SIC code definition, but are not infrastructure (e.g. Swissport, a firm focused on ground handling). Similar problems occur for other industry codes, such as SIC 4011 "Railroads, line-haul operating" which includes both integrated railroads and pure rolling stock operators. Likewise, GICS 50102010 "Wireless Telecommunication Services" also includes cellular service providers that do not necessarily own a network, so called Mobile Virtual Network Operators (MVNO). The latter may not be considered infrastructure as the defining characteristic of operating an infrastructure asset – in this case the mobile network – is not fulfilled. A further issue arises due to erroneous industry codes in the Thomson Worldscope database. Misassignments occur due to a lack of research accuracy or due to changes in the companies' business scope over time. For instance, airlines which should be correctly classified under the Primary SIC 4512, are sometimes wrongly classified under the Primary SIC 4581.

Due to the two above illustrated problems a manual check of the business scope of all long-listed companies is inevitable to ensure an unbiased infrastructure sample. To achieve this vertical delineation all companies are evaluated in a two-step procedure. First, it is checked whether the companies own or have a concession for physical infrastructure assets (asset test). This implies that other infrastructure related businesses such as network services (e.g. shipping lines, airlines, railways without own tracks), capacity resellers (e.g. electricity resellers, mobile virtual network operators), infrastructure construction firms and equipment suppliers (e.g. highway constructors, rolling stock manufacturers) and infrastructure service providers (e.g. road cleaners, airport freight handlers, railcar lessors, power plant maintenance) are excluded – as detailed in Table 2.2. Secondly, the sample is restrained to companies that generate more than 50% of their revenues in core infrastructure (revenue test).

Asset test The asset test checks whether a candidate sample firm owns or has a concession for a physical infrastructure asset. The indicators in Table 4.3 are used to objectively judge whether a company controls such an asset. For example, for a highway company it is evaluated whether the firm possesses a highway, bridge or tunnel for which it charges tolls or receives other forms of payment. Indicators may include the length or the name of the facility, the number of cars/trucks served, or the fact that toll revenues are reported in the accounting data. Each firm on the long-list was screened by two researchers independently to assure a reliable classification. If the available information is insufficient to prove or falsify one of the listed indicators, the respective firm is dropped from the sample. The following sources are employed to check these indicators:

- Company business descriptions from Thomson Worldscope, Google Finance, and webpages
- Segment reporting data from Thomson Worldscope and annual reports
- Membership lists of industry associations (CDMA Development Group, GSMA, Cable Europe, NCTA)

- Regulatory filings and databases (FCC)

Table 4.3: Indicators for infrastructure asset test

Sector	Indicators for physical infrastructure
Satellite	Indication of satellites (e.g. number of satellites, types of satellites)
Wireless	All operators of GSMA or CDMA networks (as of www.gsmworld.com and www.cdg.org)
Fixed-line	Indication of fixed-line network (e.g. region, number of customers connected, network map, network type: copper vs. fibre); For U.S.: all ILECs in FCC database (fjallfoss.fcc.gov) incl. all former Baby Bells; For Brazil: all former "Baby Telbras"; For Europe and ROW: all incumbents
Cable	Indication of cable system (e.g. serves a certain area with cable TV, number of customers connected); For U.S.: members of NCTA (www.ncta.com); For Europe: members of Cable Europe (www.cableeurope.eu)
Airports	Indication of airport/terminal (e.g. location of airport, number of passengers); Segment reporting with aviation and other segments (typically non-aviation, ground-handling)
Ports	Indication of port facilities (e.g. location of port, number of berths/piers, location of container terminals, installed handling capacity, types of cranes)
Highways	Indication of highway/bridge/tunnel (e.g. length or names, certain regions/cities, map of network); Indication of toll revenues in segment reporting
Rail	Indication of rail network/stations/freight facilities (e.g. network length, network subsidiary, number of stations/shunting yards/intermodal loading facilities); Railroads in countries with separate network management companies (e.g. U.K., Sweden) are excluded
Pipelines	Indication of pipeline network (e.g. length of network, location of network, type of pipelines); Indication of oil & gas storage facilities (e.g. capacity, types or location of storage facilities)
Electricity	Indication of transmission & distribution network (e.g. length of network, location of network); Indication of power plants (e.g. installed capacity, number of plants, types or location of plants)
Water	Indication that company has treatment plants and/or distribution network (e.g. length of network, number of customers connected, area of network, provision of water and wastewater services to customers)
Gas	Indication of transmission & distribution network (e.g. length, location, number of customers served); Indication of storage facilities (e.g. capacity, location)

Source: Author

Revenue test After testing whether the respective company controls any physical infrastructure, it is evaluated whether it generates more than 50% of its revenues in infrastructure.[4] For all non-diversified infrastructure firms this is a trivial con-

[4]Revenues are used instead of EBITDA or assets due to the better data availability.

clusion. For diversified firms, the necessary segment reporting data are obtained from Thomson Worldscope or if not available from annual reports. If no data are available the company is excluded from the sample. For some vertically integrated companies - such as integrated electricity utilities, telecoms, and railways - the segment reporting does not unveil the share of core infrastructure revenues as their segment reporting often follows a product or customer logic instead of a value chain logic separating the network component. For example, the revenues a telecommunication company derives from providing phone services to customers are not separated from the internal value creation of the cable infrastructure which is only reflected in internal transfer prices. In these cases, companies are admitted to the sample as the reality of infrastructure markets does not present unbundled assets and the value creation share of the core infrastructure business is typically significant.[5] As a result of the revenue test, any companies deriving more than 50% of their revenues from network services or ancillary services, the supply of infrastructure technology or the construction of infrastructure are excluded from the long list. For example, Time Warner is excluded as it generates more than 50% of revenues in media despite its strong cable business. Also several companies that are sometimes considered infrastructure by other authors or in certain indices are excluded. For instance, Hochtief and Ferrovial – despite being major transportation infrastructure operators – generate the majority of their revenues in construction. Likewise, several integrated Japanese urban railway operators are dropped due to their significant diversification into the retail business. The revenue test procedure for each company is performed by two researchers independently to minimize classification errors. As a result, 1,733 companies are admitted into the final sample. The high share of companies dropped from the initial long-list of 3,298 is due to the broad definition of SIC and GICS codes and the employed search procedure.

[5]For example, electricity prices typically consist of one third for generation, one third for transmission and distribution, and one third for retail (when excluding taxes, e.g. compare Bundesnetzagentur (2010)). Hence, the infrastructure business accounts for two thirds of the total value creation.

4.1.4 Exclusion of non-equity securities

In the next step, the sample is restricted to equity only as the risk characteristics of other types of securities may differ. Other security types include funds (e.g. closed-end and income funds), trusts (e.g. income and royalty trusts), depository receipts (e.g. ADRs and GDRs)[6], and bonds. Funds and trusts have a peculiar financial structure as well as specific governance and incentive systems resulting in a potentially different risk profile in comparison to regular equities (Lawrence and Stapledon (2008), Davis (2009), Weber (2009), Probitas Partners (2007)). In addition, fund-level diversification impacts the level of risk and impedes an unambiguous industry classification. Depository receipts represent double counts in the sample if their underlying home country stock is also represented in the sample. Bonds are structurally different financing instruments as they grant contractual interest payments (fixed-income) and repayment at face value after expiry, whereas equity constitutes a time-unbounded residual claim on the firm's cash flows.

To identify the above non-equity securities, I follow Ince and Porter (2006) and screen the preliminary sample for any entities that do not carry EQ in the Thomson Datastream (TDS) field TYPE. All entities that carry the labels for closed-end funds "CF", unit trusts "UT", investment trusts "INVT", Global Depository Receipts "GDR", American Depository Receipts "ADR", and bonds "BD" are removed from the sample.[7] As security type classification errors in TDS are well documented, I additionally search the Datastream variable NAME for key words that may indicate non-equity securities as suggested in Ince and Porter (2006) and Griffin et al. (2006). The procedure is to search the NAME field for phrases indicating funds, trusts, depository receipts, duplicates, debt securities, warrants, and expired securities; create a candidate list for exclusion of companies containing these words;

[6]Though ADRs are excluded in the initial industry code based firm download from TWS as described in section 4.1.2), it is screened again to account for errors in TWS/TDS.

[7]The industry code screening as additionally proposed in Griffin et al. (2006) does not yield additional exclusions. This procedure involves searching for the Datastream industry codes that indicate investment trusts (ITGSP, IVTUK, ITVNT, ITSPL, ITINT, INVTO, ITEMG, ITVCT), investment companies (INVNK, INVCO, OEINC), unit trusts (UNITS), currency funds (CURFD), exchange traded funds (EXTRF), off-shore funds (OFFSH), and property funds (INSPF).

and manually review this list for any firms that should not be removed from the sample. The following key words are used as suggested by Ince and Porter (2006) and Griffin et al. (2006):

1. Investment trusts, unit trusts, real estate trusts, mutual funds, index funds, and limited partnerships: ut, it., .it, inv tst, rlst it, unt tst, investment trust, unit trust, lp, unit, tst, unt, uts, 500, defer, dep, depy, elks, etf, fund, fd, idx, index, mips, mits, mitt, mps, nikkei, note, perqs, pines, prtf, ptns, ptshp, quibs, quids, rate, rcpts, recee, reit, retur, score, spdr, strypes, toprs, wts, xxxxx, yield, yl, lp, partnership, limited partn[8]

2. Depository receipts: adr, gdr

3. Duplicates: duplicate, dupl, dup, dupe, 1000dup

4. Debt securities: debenture, debt, bond, deb, db, dcb

5. Warrants: warrant, warrants, wts, wts2, warrt

6. Expired securities: expired, expiry, expy

In addition, selected country-specific filters are applied as proposed in Griffin et al. (2006), though these keywords matched only two additional funds. In total, 92 entities are eliminated based on the non-equity screening procedure. In a next step, the preliminary sample is screened for firms that have at least 18 consecutive months of local currency non-zero return datapoints during the time period from 1973 till 2009 (for which Thomson Datastream data are available). As a result, the final infrastructure sample contains 1,458 companies.

4.2 Reference firm sample

An analysis of the risk characteristics of infrastructure is only useful if compared against a benchmark. Therefore, a reference sample of listed firms from other industry sectors in the sense of "market average" companies is required. Due to

[8]The last two key words are not listed in Ince and Porter (2006) and Griffin et al. (2006), but perform well to identify limited partnerships.

its wide coverage and prominent use in the investment community, I use the MSCI All Country World Index[9] – hereafter referred to as MSCI sample. I use the MSCI All Country World instead of the more customary MSCI World, since the earlier also includes emerging market firms and therefore provides a better benchmark for my global infrastructure sample.[10] Notwithstanding, some biases between the infrastructure and the MSCI sample in terms of liquidity, size, and survivorship bias remain, which need to be addressed by the respective analysis methodologies (e.g. sections 5.2.3, 6.2.2, and 7.2.1).

As of 31 December 2009, the MSCI All Country World Index contained 2,423 companies across all industries from 45 developing and emerging countries and accounts for about 53% of world market capitalization.[11] I exclude all companies from the MSCI sample that are also part of the infrastructure sample to assure that the MSCI sample is non-infrastructure only. After eliminating redundant companies, screening for non-equity security types, and considering the availability of local currency return data, the MSCI sample is effectively reduced to 2,079 companies.

4.3 Analysis of sample constitution

In this section the composition of the infrastructure sample is analyzed with regard to industry, region, country, and firm size. Besides giving an insight into which infrastructure firms are actually analyzed, this section aims at comparing it to the reference sample in order to judge whether the two samples can be reasonably compared to each other. The composition analysis is mostly based on the number of

[9]Source: MSCI Barra. The MSCI data contained herein is the property of MSCI Inc. (MSCI). MSCI, its affiliates and any other party involved in, or related to, making or compiling any MSCI data, make no warranties with respect to any such data. The MSCI data contained herein is used under license and may not be further used, distributed or disseminated without the express written consent of MSCI.

[10]In addition to the 24 developed countries of the MSCI World, the MSCI All Country World contains firms from 21 emerging markets, though no "frontier" markets.

[11]World market capitalization according to the World Federation of Exchanges amounted to $46.9 trillion as of 31 December 2009.

firms as most analyses in chapters 5 and 6 weight firms of different sizes equally.[12] But, I also provide a composition analysis based on market capitalization, since the inflation analyses in chapter 7 is based on return data weighted by market capitalization. The following composition analyses are based on all firms for which at least 18 consecutive months of local currency non-zero return data are available over the time period from 1973 till 2009. In total, the infrastructure sample complying with these data limitations contains 1,458 companies, and the reference sample 2,079 companies.[13]

4.3.1 Industry and region

The 1,458 infrastructure firms are split across 13 subsectors and six world regions as detailed in Table 4.4. The 815 utilities (56%) constitute the largest sector in the sample, followed by telecommunication with 432 firms (30%), and transport with 211 firms (14%). Amongst utilities, the electricity subsector contributes the largest number of firms (499; 34%), followed by gas (129; 9%) and multi-utilities (116; 8%). Telecommunication is dominated by fixed-line (184, 13%) and wireless (164, 11%), while within transport, the relative contribution of airports, pipelines, ports, highways, and railroads is fairly equal, all ranging between 27 and 55 firms (2% to 4%). With regard to market capitalization (Table 4.6) a similar picture emerges, though telecommunication ($2,982 billion; 50%) takes a larger share at the expense of utilities ($2,463 billion; 41%) and transport ($534 billion; 9%). This effect is primarily driven by the higher average market capitalizations among wireless firms. Similarly, multi-utilities make up a larger relative share due to their large average size. The relative shares of most other subsectors are similar to the analysis based on the number of firms, though at a lower level. In summary, it can be concluded that the infrastructure sample is biased towards utilities and telecommunication firms,

[12] For example, the descriptive and regression risk analysis in chapter 5 and the analysis of the impact of regulation in chapter 6.

[13] In the course of this dissertation, other subsamples of differing sizes are used for specific analyses if certain datatypes are not available for a select firm-year-combination. In this case, the respective methodology section provides the adjusted sample composition by sector and region.

particularly towards electricity, wireless, and fixed-line. However, this overrepresentation can be resolved by sector-specific analysis revealing individual investment characteristics. Among MSCI firms, the relative distribution of different industries is more balanced as illustrated in Table 4.5. Most industries do not exceed a relative share of 15% in terms of number of firms, with the only exception being consumer with 525 firms representing 25% of the sample.

Table 4.4: Number of infrastructure firms by sector and region

	North America	**Latin America**	**Western Europe**	**Eastern Europe**	**Africa, Middle-East**	**Asia-Pacific**	**World**
Infrastructure	465	139	272	58	44	480	1,458
Telecommunication	169	41	69	15	26	112	432
Transport	33	13	45	6	2	112	211
Utilities	263	85	158	37	16	256	815
Satellite	15	0	5	1	2	10	33
Wireless	56	10	25	5	20	48	164
Fixed-line	73	27	32	6	3	43	184
Cable	25	4	7	3	1	11	51
Airports	0	3	12	2	0	10	27
Ports	1	5	7	2	2	38	55
Highways	0	3	9	0	0	31	43
Rail	13	1	12	0	0	23	49
Pipelines	19	1	5	2	0	10	37
Electricity	127	70	101	27	12	162	499
Water	24	6	19	1	1	20	71
Gas	52	8	9	7	1	52	129
Multi	60	1	29	2	2	22	116

Source: Rothballer and Kaserer (2011)

The relative regional composition of the infrastructure and the MSCI sample is fairly aligned. North America makes up 465 or 29% of the 1,458 firms in the infrastructure and 603 or 32% of the 2,079 MSCI firms; Western Europe contributes 19% in both samples (272 and 397 firms); and Asia Pacific represents 33% (480) and 43% (890), respectively. The less represented world regions Latin America (10% and 4%), Eastern Europe (4% and 2%), and Africa & Middle East (3% in both samples) are also relatively equal. A similar result is found when analyzing market capitalization as given in Table 4.6. While the infrastructure sample contains a

Table 4.5: Number of MSCI firms by sector and region

	North America	**Latin America**	**Western Europe**	**Eastern Europe**	**Africa-Middle East**	**Asia-Pacific**	**World**
Basic materials	48	17	40	2	17	114	238
Consumer	156	33	107	6	9	214	525
Banks	26	10	46	18	11	95	206
Insurance	39	1	29	1	3	21	94
Other financials	53	10	27	3	10	97	200
Healthcare	57	0	31	1	3	30	122
Construction	13	4	21	2	4	44	88
Industrials	83	4	52	0	6	143	288
Oil & Gas	63	5	27	5	2	48	150
Technology	65	0	17	1	1	84	168
Total	603	84	397	39	66	890	2,079

Note: Basic materials includes basic resources and chemicals; Consumer includes consumer goods (automobiles & parts, food & beverage, personal & household goods) and consumer services (media, retail, travel & leisure); Other financials includes real estate.
Source: Rothballer and Kaserer (2011)

lower share of North American firms (28% or \$1,696 billion out of \$5,978 billion vs. 42% or \$11,400 billion out of \$26,885 billion of market capitalization), the infrastructure sample is more biased towards Western European companies (37% or \$2,192 billion vs. 28% or \$7,434 billion). In both samples, Asia-Pacific amounts to 25% of market capitalization, and Latin America, Eastern Europe, and Africa & Middle-East make up less than 5% of market capitalization, respectively. Overall, the regional composition of the infrastructure sample is relatively well matched by the MSCI sample.

Table 4.6: Market capitalization of sample firms by sector and region

	North America	**Latin America**	**Western Europe**	**Eastern Europe**	**Africa, Middle-East**	**Asia-Pacific**	**Total**
MSCI	11,400	715	7,434	204	347	6,786	26,885
Infrastructure	1,696	253	2,192	99	237	1,501	5,978
Telecom	783	136	1,030	57	209	767	2,982
Transport	198	16	99	3	0	216	534
Utilities	715	101	1,063	39	27	518	2,463
Satellite	46	0	19	1	0	9	76
Wireless	231	60	727	29	193	589	1,800
Fixed-line	377	73	270	26	15	158	918
Cable	129	4	13	1	1	12	159
Airports	0	4	22	2	0	16	43
Ports	0	3	6	1	0	47	56
Highways	0	6	64	0	0	37	107
Rail	127	2	3	0	0	114	246
Pipelines	70	2	4	1	0	4	81
Electricity	370	89	558	36	21	405	1,500
Water	17	8	59	0	0	11	95
Gas	85	4	51	2	0	47	189
Multi	243	0	395	0	6	55	699

Note: Market capitalization in $ billion, average of the period from 1 January 2005 till 31 December 2009 using monthly data.
Source: Author

4.3.2 Country

The infrastructure firms are domiciled in 71 different countries, and the MSCI firms in 46 countries, as detailed in Table 4.7 and Table 4.8. Both the infrastructure and the MSCI sample contain firms from all developed countries (as defined by the MSCI country classification).[14] The MSCI sample is limited to firms from developed and emerging markets, whereas the infrastructure sample also includes firms from frontier markets such as Bangladesh, Croatia, Kenya, Saudi Arabia, and Vietnam. While in the infrastructure sample 583 or 40% out of the total 1,458 firms are from emerging and frontier countries, the corresponding share in the MSCI sample is 28% (587 out of 2,079). In both samples the majority of firms is U.S.-based (397 or 27% in the infrastructure sample vs. 525 or 25% in the MSCI sample). All other countries make up less than 5% of firms in both samples, with the exception of China which accounts for 119 or 8% of the infrastructure firms, and Japan which makes up 318 firms or 15% of the MSCI sample. Overall, it can be concluded that both samples are fairly similar with regard to their country representation. The slightly higher exposure of the infrastructure sample to emerging markets, especially as it includes firms from frontier markets, should be taken into account in the empirical analysis.[15]

4.3.3 Firm size

Table 4.9 and Table 4.10 show the relative distribution of the infrastructure and the MSCI sample in terms of firm size as measured by revenues and market capitalization. In both tables "small" refers to firms with up to $100 million, "mid" to up to $500 million, "large" to up to $10 billion, and "very large" to more than $10 billion of revenues or market capitalization, respectively.

The infrastructure sample is fairly well distributed across the different size clus-

[14] The use of developed, emerging, and frontier markets/countries in this section follows the MSCI country classification. Refer to www.msci.com/products/indices/market_classification.html for more information (retrieved on 23 March 2012).

[15] This issue is addressed in the empirical analyses either by an emerging market dummy (section 5.2.3) or by the country governance variable (section 6.2.1).

Table 4.7: Number of infrastructure firms by country

Developed markets		**Emerging markets**		**Emerging markets (cont'd)**	
Australia	31	Argentina	15	Malta	1
Austria	8	Bahrain	1	Mexico	13
Belgium	9	Bangladesh	2	Morocco	2
Canada	64	Bermuda	3	Oman	8
Denmark	4	Brazil	66	Pakistan	13
Finland	6	Cayman Islands	1	Peru	7
France	26	Chile	31	Philippines	18
Germany	41	China	119	Poland	11
Greece	9	Colombia	4	Qatar	2
Hong Kong	38	Croatia	2	Romania	2
Ireland	1	Czech Republic	16	Russian Federation	52
Italy	39	Egypt	5	Saudi Arabia	4
Japan	51	Estonia	1	Slovakia	1
Luxembourg	6	Hungary	6	Slovenia	3
Netherlands	7	India	33	South Africa	4
New Zealand	16	Indonesia	9	Sri Lanka	3
Norway	5	Israel	7	Taiwan	12
Portugal	7	Jordan	3	Thailand	19
Singapore	7	Kenya	2	Turkey	8
Spain	15	Korea (South)	23	United Arab Emirates	3
Sweden	11	Kuwait	2	Venezuela	3
Switzerland	18	Latvia	1	Vietnam	1
United Kingdom	59	Lithuania	7	Zimbabwe	1
United States	397	Malaysia	33		
Total	875				583

Source: Author

Table 4.8: Number of MSCI firms by country

Developed markets		**Emerging markets**	
Australia	64	Brazil	48
Austria	6	Chile	11
Belgium	11	China	48
Canada	78	Colombia	7
Denmark	13	Cyprus	1
Finland	15	Czech Republic	1
France	64	Egypt	9
Germany	45	Hungary	3
Greece	9	India	54
Hong Kong	84	Indonesia	18
Ireland	4	Israel	12
Italy	24	Korea (South)	89
Japan	318	Malaysia	31
Luxembourg	1	Mexico	18
Netherlands	21	Morocco	3
New Zealand	2	Philippines	8
Norway	7	Poland	16
Portugal	5	Russian Federation	17
Singapore	24	South Africa	42
Spain	21	Taiwan	113
Sweden	27	Thailand	20
Switzerland	33	Turkey	18
United Kingdom	91		
United States	525		
Total	1492		587

Source: Author

ters. "Small"- and "mid"-sized firms make up between 20% and 25% of the sample, "large" firms around 40%, and "very large" firms less than 10% of the sample, both in terms of sales and market capitalization. Ports, pipelines, satellites, highways, and water utilities are the sectors with the highest share of firms with "small" revenues, whereas wireless, fixed-line, railroads, and multi-utilities contain the largest shares of "very large" firms both in terms of sales and market capitalization. Overall there is no particular size bias within the infrastructure sample, as all subsectors contain a significant share of at least "large" firms.

When comparing the size composition of the infrastructure to the MSCI sample, it becomes obvious that there is a systematic bias. While 43% (54%) of the infrastructure firms are "large" or "very large" with regard to sales (market capitalization), the respective share in the reference sample is 91% (100%). This is because the MSCI All Country World is a large-cap index, explicitly excluding small- and mid-cap firms. The different firm size also entails a difference in the trading liquidity of the two samples. Infrastructure firms, which are smaller on average, tend to be traded less liquidly than the larger MSCI firms. As these sample biases could have a material impact on the investment characteristics, it is corrected for in the risk and inflation hedging analyses in the chapters 5, 6, and 7.[16]

In order to give the reader an idea of the typical infrastructure firms represented in the sample, Table 4.11, Table 4.12, and Table 4.13 present the ten largest infrastructure firms by market capitalization for each subsector. The largest firms with a market capitalization above $100 billion include China Mobile ($182.0 billion), AT&T ($159.9 billion), Vodafone ($142.2 billion), Electricite De France ($129.7 billion), Telefonica ($104.2 billion), and Verizon Communications ($100.2 billion). The most valuable transport infrastructure firms are East Japan Railway ($27.7 billion), the pipeline firm Transcanada ($17.4 billion), the highway operator Atlantia ($15.5 billion), the port of Shanghai ($13.4 billion), and Aeroport de Paris ($8.5 billion). Among utilities, the multi-utility E.On ($89.2 billion), the water provider

[16] This is addressed by the explicit exclusion of "small" firms and illiquid stocks (sections 5.3.3 and 7.2.1), or by the control variables for size and liquidity in the regressions (sections 5.2.3 and 6.2.2).

Table 4.9: Sample firms by revenue

	"Small"	**"Mid"**	**"Large"**	**"Very large"**	**n/a**	**Total**
MSCI	1%	8%	64%	27%	1%	2,079
Infrastructure	23%	24%	37%	6%	10%	1,458
Telecom	20%	23%	41%	9%	6%	432
Transport	38%	29%	25%	2%	5%	211
Utilities	21%	22%	39%	6%	13%	815
Satellite	39%	27%	27%	3%	3%	33
Wireless	16%	18%	47%	12%	7%	164
Fixed-line	17%	26%	39%	10%	8%	184
Cable	25%	29%	41%	4%	0%	51
Airports	19%	52%	19%	0%	11%	27
Ports	55%	33%	11%	0%	2%	55
Highways	37%	35%	21%	0%	7%	43
Rail	31%	20%	37%	10%	2%	49
Pipelines	41%	11%	41%	0%	8%	37
Electricity	20%	22%	37%	5%	16%	499
Water	46%	28%	20%	1%	4%	71
Gas	22%	29%	40%	4%	5%	129
Multi	8%	12%	56%	12%	12%	116

Note: "Small" refers to firms with up to \$100 million, "mid" to up to \$500 million, "large" to up to \$10 billion, and "very large" to more than \$10 billion of revenues.
Source: Author

Table 4.10: Sample firms by market capitalization

	"Small"	**"Mid"**	**"Large"**	**"Very large"**	**n/a**	**Total**
MSCI	0%	0%	70%	30%	0%	2,079
Infrastructure	22%	24%	44%	10%	0%	1,458
Telecom	23%	18%	44%	15%	0%	432
Transport	18%	27%	46%	8%	0%	211
Utilities	22%	26%	44%	8%	0%	815
Satellite	18%	30%	48%	3%	0%	33
Wireless	18%	12%	46%	24%	0%	164
Fixed-line	29%	20%	40%	11%	0%	184
Cable	24%	24%	47%	6%	0%	51
Airports	7%	19%	74%	0%	0%	27
Ports	27%	31%	40%	2%	0%	55
Highways	2%	28%	63%	7%	0%	43
Rail	22%	24%	35%	18%	0%	49
Pipelines	27%	32%	32%	8%	0%	37
Electricity	26%	23%	43%	8%	0%	499
Water	15%	44%	39%	1%	0%	71
Gas	21%	38%	37%	4%	0%	129
Multi	12%	15%	59%	15%	0%	116

Note: "Small" refers to firms with up to $100 million, "mid" to up to $500 million, "large" to up to $10 billion, and "very large" to more than $10 billion of market capitalization.
Source: Author

Veolia ($23.3 billion), and the gas utility Gas Natural ($17.8 billion) lead in their respective subsectors. The cable provider Comcast ($41.9 billion) and the satellite firm DirecTV ($25.2 billion) rank first in the other telecom subsectors.

Table 4.11: Ten largest telecom firms by market capitalization

Satellite		**Wireless**	
DirecTV	25.2	China Mobile	182.0
SES	9.0	Vodafone Group	142.2
Dish Network	6.1	Telefonica	104.2
Eutelsat Communications	5.1	Verizon Communications	100.2
Sirius XM Radio	4.8	Deutsche Telekom	72.7
XM Satellite Radio Holdings	4.4	NTT Docomo	72.6
Inmarsat	3.6	France Telecom	71.2
Panamsat	3.5	Orange	62.6
Shin Corporation	2.5	Telefonica Moviles	60.4
Sky Perfect Jsat Holdings	1.5	America Movil	46.7
Fixed-line		**Cable**	
AT & T	159.9	Comcast	41.9
Bellsouth	75.2	TCI Group	31.5
Nippon Telegraph & Telephone	72.0	Time Warner Cable	22.6
MCI Communications	35.5	Shaw Communications	6.8
Telecom Italia	32.7	Cablevision Systems	5.8
BT Group	32.6	Virgin Media	5.5
Koninklijke KPN	26.6	Jupiter Telecommunications	5.4
BCE	23.3	Liberty Global	5.4
Tecnost	22.4	Unitedglobalcom	3.8
China Unicom	20.7	ZON Multimedia	3.3

Note: Market capitalization in $ billion, average of the period from 1 January 2005 till 31 December 2009 using monthly data. The assignment of integrated telecom firms to either the wireless or the fixed-line subsector is based on the relative contribution of each segment to the overall revenues.
Source: Author

Table 4.12: Ten largest transport firms by market capitalization

Airports		**Pipelines**	
ADP	8.5	Transcanada	17.4
Fraport	5.4	Spectra Energy	13.9
Shanghai International Airport	5.1	Enbridge	12.5
Kobenhavns Lufthavne	2.5	El Paso	9.0
Airports Of Thailand	1.9	Kinder Morgan Energy Partners	8.6
Auckland International Airport	1.8	Koninklijke Vopak	2.9
Flughafen Zurich	1.6	Southern Union Company	2.9
Grupo Aeroportuario Del Pacifico	1.6	Transneft	2.2
Flughafen Wien	1.6	Ultrapar Participacoes	1.6
Guangzhou Baiyun International	1.5	Altagas	1.3
Ports		**Highways**	
Shanghai International Port Group	13.4	Atlantia	15.5
China Merchants Holdings International	8.0	Abertis Infraestructuras	15.2
Mundra Port & Special Economic Zone	5.2	Autoroutes du Sud de la France	14.3
Hamburger Hafen und Logistik	3.8	Autoroutes Paris-Rhin-Rhone	9.0
Pjsc Novorossiysk Commercial Sea Port	2.9	Brisa-Auto-Estradas De Portugal	6.2
Tianjin Port	2.6	CIA Concessoes Rodoviarias	5.2
Kamigumi	2.2	Transurban Group	5.0
Santos Brasil Participacoes	2.1	Plus Expressways	4.3
Shenzhen Yan Tian Port Holdings	1.7	Jiangsu Expressway	3.4
Forth Ports	1.3	Shandong Expressway	2.5
Railroads			
East Japan Railway	27.7		
Burlington Northern Santa Fe	27.3		
Union Pacific	27.0		
Daqin Railway	22.8		
Canadian National Railway	22.2		
Central Japan Railway	20.2		
Norfolk Southern	18.7		
CSX	15.7		
MTR Corporation	14.7		
West Japan Railway	8.3		

Note: Market capitalization in $ billion, average of the period from 1 January 2005 till 31 December 2009 using monthly data.
Source: Author

Table 4.13: Ten largest utility firms by market capitalization

Electricity		**Gas**	
Electricite De France	129.7	Gas Natural	17.8
Iberdrola	44.9	Kinder Morgan	13.5
Exelon	40.6	Tokyo Gas Company	12.2
Endesa	39.4	Snam Rete Gas	11.7
Electrabel	38.7	Lattice Group	10.7
Tokyo Electric Power Company	36.7	Osaka Gas Company	7.9
NTPC	29.2	Panhandle	7.4
TXU	28.6	Questar	7.2
CEZ	26.5	Columbia Energy Group	5.7
Southern Company	26.1	EQT	5.2
Water		**Multi**	
Veolia Environnement	23.3	E.On	89.2
Thames Water	7.8	GDF Suez	60.9
Severn Trent	6.0	Enel	56.2
Aguas De Barcelona	4.2	RWE	48.6
AWG	3.6	National Grid	31.1
Compania Saneamento Basico Sao Paulo	3.5	Duke Energy	25.6
American Water Works	3.3	Dominion Resources	25.2
Pennon Group	3.3	Centrica	21.0
Southern Water	3.0	Scottish & Southern Energy	19.8
Aqua America	2.8	Public Service Enterprise Group	17.7

Note: Market capitalization in $ billion, average of the period from 1 January 2005 till 31 December 2009 using monthly data.
Source: Author

4.4 Firm-level data

4.4.1 Datatypes and time series

Thomson Datastream (TDS) is used to retrieve the time series of various datatypes for all firms in the infrastructure and the MSCI sample. Datatypes include both stock market data (e.g. return index, trading volume, valuation ratios) and accounting data (e.g. sales, EBIT, dividends). Table 4.14 provides an overview of all TDS datatypes and mnemonics, the used variable name, the data frequency, and the datatype definition. Accounting data are mostly retrieved on an annual basis, while stock market data are retrieved on a monthly basis. Each monetary datatype is retrieved in USD as well as in local currency. The maximum used time series ranges from January 1973 till December 2009, i.e. it covers 37 years.[17] However, the average return time series in the infrastructure sample contains 144 monthly observations, i.e. covers 12 years, as the time series' lengths differ by company depending on the initial listing and the commencement of data recording by TDS. In contrast, the average return time series in the MSCI sample covers 244 months, i.e. 20 years.

In addition to the time series data, several static datatypes are retrieved from TDS and TWS. Those include the country of the headquarter (tf.AddressCountry), the company status "active vs. inactive" (tf.CompanyStatus), the assigned GICS and SIC codes (tf.GICS, tf.PrimarySICCode, tf.SICCode), the business description (tf.BusinessDescriptionExtended), and the business segment reporting data (ws.BusinessSegment1Description and ws.BusinessSegment1SICCode for up to 9 business segments). The company status is captured in the dummy variable $CompanyStatus_i$.[18] Using the headquarter country, the variable $Emerging\_D_i$ is generated by using the MSCI country classification of developed and emerging markets as depicted in Table 8.5 in the appendix. The SIC codes are counted for each firm and the total number of assigned SIC codes is expressed as the variable

[17] Thomson Datastream does not contain data prior to the start date of the retrieved time series.

[18] The i refers to the company index.

$SICs_i$. The business description and the business segment reporting data are used in the screening process described in section 4.1.3.

4.4.2 Data cleansing

To clean the return data, I apply the following screens as advocated by Ince and Porter (2006). First, I eliminate all trailing local currency zero returns from the end of the sample period to the first non-zero return. This elimination is necessary as TDS repeats the last valid data point for delisted firms as a dummy record. The danger of losing valid zero-returns at the end of the sample is negligible as the sample period ends in December 2009, whereas data are retrieved until June 2010. Second, I drop all observations when the end-of-previous-month return index is less than 0.1 to avoid errors from calculating returns from rounded index values when index values are small.[19] Third, I remove unrealistic returns from the data by setting to missing any return above 300% that is reversed within one month.[20] Another issue with TDS data, which is not yet documented in the literature, relates to currency conversions. When using USD data from inactive companies the return index may still vary due to exchange rate movements despite the fact that trading of the stock has ceased. Thus, for USD returns I apply the same cut-off point for eliminating trailing zero returns as determined for local currency returns. For other datatypes than returns the same restrictions apply as these data are only used if the corresponding return data are available for the particular firm and time period.

4.4.3 Calculation of variables

Further variables are computed based on the basic datatypes available on TDS. Table 4.15 provides an overview of all calculated market value, trading liquidity, and accounting variables including the formula how they are derived from the TDS datatypes.

[19]Common practice in TDS is rounding to the second digit.

[20]The 300% threshold is suggested by Ince and Porter (2006). Though being somewhat arbitrary, it is evaluated to perform well.

Table 4.14: Thomson Datastream datatypes and definitions

TDS datatype and mnemonic	Variable name	Frequency	TDS definition
Stock market data			
Return index (RI)	$ReturnIndex_{i,t}$	monthly	Shows theoretical growth in value of a share holding over a specified period, assuming that dividends are re-invested to purchase additional units of an equity or unit trust at the closing price applicable on the ex-dividend date
Bid price (PB)	$Bid_{i,t}$	monthly	Bid price offered at close of market
Ask price (PA)	$Ask_{i,t}$	monthly	Asking price quoted at close of market
Equity market value (MV)	$EquityMV_{i,t}$	monthly	Share price multiplied by the number of ordinary shares in issue
Market-to-book ratio (MTBV)	$MarketBook_{i,t}$	monthly	Market value of ordinary equity divided by balance sheet value of ordinary equity
Price-to-earnings ratio (PE)	$PriceEarnings_{i,t}$	monthly	Official closing price divided by the earnings rate per share at the required date
Trading volume (VO)	$TradingVolume_{i,t}$	monthly	Number of shares traded for a stock on a particular day
Number of shares (NOSH)	$Shares_{i,t}$	monthly	Total number of ordinary shares that represent the capital of the company
Accounting data			
Sales (DWSL)	$Sales_{i,t}$	yearly	Gross sales and other operating revenue less discounts, returns and allowances
EBIT (DWEB)	$EBIT_{i,t}$	yearly	Earnings of a company before interest expense and income taxes
Net profit (DWNP)	$NetProfit_{i,t}$	yearly	Income after all operating & non-operating income & expense, reserves, income taxes, minority interest & extraordinary items
Dividend payout ratio (POUT)	$DivPayout_{i,t}$	yearly	Ratio of dividends per share to earnings per share for the last financial period
Capital expenditure (DWCX)	$CAPEX_{i,t}$	yearly	Capex represents the funds used to acquire fixed assets other than those for acquisitions, including additions to property, plant & equipment as well as investments in machinery & equipment
Total assets (DWTA)	$Assets_{i,t}$	yearly	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
Equity book value (DWSE)	$EquityBV_{i,t}$	yearly	Common shareholders' investment in a company
Debt book value (WC03255)	$DebtBV_{i,t}$	monthly	All interest bearing and capitalized lease obligations (long and short term debt)

Source: Modified from Rothballer and Kaserer (2011)

Table 4.15: Calculation of variables

Variable	Formula
Market value variables	
Return (continuously compounded)	$R_{i,t} = ln\left(\frac{ReturnIndex_{i,t}}{ReturnIndex_{i,t-1}}\right)$
Leverage	$Leverage_{i,t} = \frac{DebtBV_{i,t}}{EquityMV_{i,t}}$
Firm value	$FirmValue_{i,t} = DebtBV_{i,t} + EquityMV_{i,t}$
Earnings-to-price ratio	$EarningsPrice_{i,t} = 1/PriceEarnings_{i,t}$
Book-to-market ratio	$BookMarket_{i,t} = 1/MarketBook_{i,t}$
Trading liquidity variables	
Relative trading volume	$RelTradVol_{i,t} = \frac{TradingVolume_{i,t}}{Shares_{i,t}}$
Bid-ask spread	$BidAskSpread_{i,t} = \frac{Ask_{i,t}-Bid_{i,t}}{(Ask_{i,t}+Bid_{i,t})/2}$
Trading continuity	$TradCont_i = \frac{1}{T_i}\sum_{t_i=1}^{T_i}\begin{cases}0 \text{ if } R_{i,t}=0\\1 \text{ otherwise}\end{cases}$ where T_i is the length of the respective time series
Accounting variables	
Sales growth	$SalesGrowth_{i,t} = ln\left(\frac{Sales_{i,t}}{Sales_{i,t-1}}\right)$
Return on assets	$ROA_{i,t} = \frac{EBIT_{i,t}}{Assets_{i,t}}$
Return on equity	$ROE_{i,t} = \frac{NetProfit_{i,t}}{EquityBV_{i,t}}$
Capital expenditure volatility	$CapexVola_{i,t} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\frac{CAPEX_{i,t}}{Sales_{i,t}} - (\frac{1}{T}\sum_{t=1}^{T}\frac{CAPEX_{i,t}}{Sales_{i,t}}))^2}$
EBIT margin volatility	$EbitMarginVola_{i,t} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\frac{EBIT_{i,t}}{Sales_{i,t}} - (\frac{1}{T}\sum_{t=1}^{T}\frac{EBIT_{i,t}}{Sales_{i,t}}))^2}$

Source: Author

4.5 Country-level data

4.5.1 Country governance

As a measure for each country's stage of development and the quality of its institutional and political environment I use the Worldwide Governance Indicators (WGI) as developed by Kaufmann et al. (1999). The six indicators capture various dimensions of governance: voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. They are measured in units ranging from about -2.5 to 2.5, with higher values corresponding to better governance outcomes. The variable $CountryGovernance_{i,t}$ is calculated by averaging the six sub-indicators for the years 2005 until 2008 using the data from Kaufmann et al. (2009).[21] The resulting country-level index data are matched to individual firms using their respective headquarter country.

4.5.2 Market competitiveness

The indicators for energy, transport and communication regulation (ETCR) as compiled by the OECD (2007) are used to measure the degree of market competitiveness of a sector in a given country. This dataset is based on a structured questionnaire on the entry regulation, the market structure, the vertical integration, and public ownership in infrastructure sectors in all OECD countries. They have been collected at an annual frequency over the period from 1975 to 2007.[22] The dataset covers electricity, gas, rail, and telecommunication.[23]

The measures and the corresponding survey questions for the sub-indicators

[21] 2009 data are not yet available. However, the impact of the missing 2009 data point is marginal, as the six indicators are relatively stable across time.

[22] The full time series is available for Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Limited data (2007 only) are available for new OECD members and enhanced engagement countries: Chile, China, Estonia, Israel, Russia, Slovenia, Brazil.

[23] The dataset also includes data on air passenger transport, road freight, and postal services, though these data are not used in this thesis.

entry regulation, market structure, vertical integration, and public ownership are specific to the particular sector and not all sub-level indicators are applicable to all sectors. For example, the questions regarding entry regulation in the electricity sector measure the terms and conditions of third party access to the transmission grid, the level of liberalization of the wholesale market, and the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier. In contrast, for the telecommunication market the respective questions assess the legal conditions of entry (free entry; franchised to 2 or more firms; franchised to 1 firm) into the trunk telephony, international, and mobile market. The public ownership indicator for the electricity sector is based on the percentage of government ownership in the largest generation, transmission, distribution, and supply companies. The vertical integration indicator is determined based on the degree of separation between transmission and generation (separate companies, accounting separation, integrated) and the overall level of vertical integration (unbundled, mixed, integrated). For each of these sub-indicators a value between 0 and 6 is assigned, where 0 refers to a competitive market and 6 describes a regulated market for a specific industry-country-year combination. The sub-indicators are then converted into sectoral indicators of market regulation mostly using equal weighting. The details of the above coding, weighting and aggregation procedures and their associated problems are discussed in Conway and Nicoletti (2006).

Due to the specific use of these data in the context of this thesis, the original OECD data are modified in two ways. First, public ownership sub-indicators are excluded from the weighted average calculation of the overall indicators as it is an unsuited proxy for market competitiveness. In addition, I compute individual indicators for fixed-line and wireless – the published OECD data only include telecommunication as one sector – based on the available raw data by applying the same coding, weighting, and aggregation procedures. Likewise to the country governance variable, data are matched to individual firms using their respective headquarter country yielding the variable $MarketCompetition_{i,t}$. For the analysis in the sections 6.2.1 and 7.3.3, the original OECD data are amended using further specific assumptions, which are detailed in the respective section.

4.5.3 Price regulation

Data on the existence of price regulation, the employed regulatory regime, and regulatory independence are obtained from a comprehensive OECD survey which is supplemented by own research. The OECD dataset covers infrastructure regulation in 25 of its 34 member countries across different sectors.[24] It has been collected through a questionnaire sent to all member states, representing the first attempt to gather a comparable cross-country dataset covering various aspects of infrastructure regulation.[25] The provided information represents the regulatory settings in late 2007/early 2008[26] without anticipation of future regulatory reforms. The answers refer to regulations and policies issued by the national governments or state/provincial governments for federal countries.[27]

The OECD questionnaire includes questions on the existence of price regulation (yes, partially, no), the applied type of price regulation (price cap, other incentive, rate-of-return, other cost-based), and the responsible regulatory body with regard to rule making, the adjudicatory function, sanctions, and licenses (regulatory authority, competition authority, environment agency, executive, parliament, other agency). Table 4.16 gives an overview of the survey questions relevant for this

[24]The same dataset is used in Égert (2009).

[25]Besides the sections on sector regulators, the regulators' powers and mandates, and price regulation (which are used in this thesis), additional sections cover concessions and franchises, investment planning, financing and incentives, and Public Private Partnerships.

[26]The questionnaire was sent to the member states on 14 November 2007, and completed by the member countries' agencies during the following months.

[27]Federal countries were asked to base their answers on institutions and regulations prevailing in the most representative sub-national entities or a subset of regions that characterize best each country's institutional and regulatory settings.

thesis and the corresponding answer coding into dummy variables.

Table 4.16: Regulation datatypes and coding

Datatype	**Question (Nr. in OECD survey)**	**Answer options and coding**
$PriceRegulation\_D_i$	Are prices regulated? (1.3.1.)	Yes, for all prices (1); Partially (0.5); No (0); Price was never regulated (0)
$IncentiveRegulation\_D_i$	For the sectors where prices are regulated, please specify how these are set? (1.3.3.)	Pure price cap (1); Other form of incentive regulation (1); Pre-determined rate-of-return (0); Other cost-based regulation (0); Unregulated (0)
$RuleMaking\_D_i$	Please identify, for each sector, which of the following bodies has the power to design specific rules for the sector. (1.2.1.)	Regulatory Authority (1); Competition Authority (1); Environment Agency (0); Executive (0); Parliament (0); Other Agency (0)
$Adjudicator\_D_i$	Please identify, for each sector, which of the following bodies has the power to implement regulation and verify compliance with the regulatory environment in the sector. (1.2.2.)	Regulatory Authority (1); Competition Authority (1); Environment Agency (0); Executive (0); Parliament (0); Other Agency (0)
$Sanctions\_D_i$	Please identify, for each sector, which of the following bodies has enforcement powers to apply fines and sanctions. (1.2.3.)	Regulatory Authority (1); Competition Authority (1); Environment Agency (0); Executive (0); Parliament (0); Other Agency (0)
$Licenses\_D_i$	Please identify, for each sector, which of the following bodies has powers to award, enforce and revoke licenses. (1.2.4.)	Regulatory Authority (1); Competition Authority (1); Environment Agency (0); Executive (0); Parliament (0); Other Agency (0)

Note: If multiple answers are given for a question on the regulatory institutions, the arithmetic average of the coded answers is used.
Source: Author (based on OECD survey questionnaire)

The dummy $PriceRegulation\_D_i$ is set equal to 1 (0.5) when the firm is subject to (partial) price regulation, and 0 otherwise.[28] The dummy $IncentiveRegulation\_D_i$ assumes 1 when incentive regulation (rate freeze, price cap, revenue cap, rate-case moratoria, yardstick) is applied, and 0 if prices are unregulated or set according to

[28]Partial price regulation means that not all of the firm's output prices are regulated.

cost-based regulation (e.g. rate-of-return (RoR)).[29] From the individual regulatory independence scores with regard to rule making, adjudicator, sanctions, and licenses an overall regulatory independence score is calculated as arithmetic average:

$$\begin{aligned} Independence\_D_i = (&RuleMaking\_D_i + Adjudicator\_D_i \\ &+ Sanctions\_D_i + Licenses\_D_i)/4 \end{aligned} \tag{4.1}$$

The OECD dataset is complemented for the missing seven OECD and 21 non-OECD countries by manual research.[30] To ensure the comparability of the data, the structure of the OECD questionnaire and its answer options are adopted. Throughout the research process the following data sources are employed:

1. Information from regulators or governments, either from their webpage or other official documents.
2. Information from previous academic publications surveying certain sectors or countries. Table 4.17 provides an overview of all used sources.
3. Direct email inquiries to governments, regulatory authorities, and experts including the questions on the existence of price regulation, the applied type of price regulation, and the degree of independence of the regulator as given in Table 4.16.
4. Information from company's annual reports, webpages or other official documents. Firm-specific data sources are used for 138 transport infrastructure firms since their regulation is typically local or regional and not necessarily the same across a given country. In contrast, for telecommunication and utilities country-wide information from the above three sources is used.

The manual research of the regulatory data was carried out in early 2011, but most of the data are as of the years 2003 to 2009, with most data points clustering

[29] A more refined classification of regimes is not feasible based on the OECD data. Notwithstanding, I use 0.5 for hybrid regimes (e.g. sliding scale, earnings sharing, price cap with cost pass-through) for manually researched data.

[30] In cases where multiple answers are stated in the OECD dataset, manual research is also used to correct those data entries.

around 2007 (as is the case for the OECD data). Though there is a minimal time mismatch, its effect is marginal as regulation is relatively sticky with few changes occuring over the years. For example, in Gaggero (2012)'s panel spanning the period from 1995 till 2004, only 18 out of 170 firms (approximately 10%) experienced a switch in the regulatory regime. As data availability and transparency is limited, data for several countries and sectors remain missing. In case there are any doubts about the data quality, data are also set to missing.

For manually researched data, the same dummy definitions as for the OECD data are used, except for $Independence\_D_i$. Since detailed data on the agency responsible for rule making, adjudicator, sanctions, and licenses are typically not available, it is set to 0 if the regulator is a governmental agency, 1 if it is an independent regulator, and 0.5 if the regulator is formally independent, but significant decision rights are wielded by the government. To assure an equal intervaling of OECD and self-collected data, the OECD data for this dummy variable are rounded to 0, 0.5, or 1.

As various infrastructure sector classification are used in the OECD dataset, for each question a specific matching is used. Table 4.18 gives an overview of this matching procedure. Due to the higher granularity of the OECD data for some sectors, generic assumptions on the relative representation of these sectors in given firms are used. This weighting procedure entails that dummy values are not exclusively 0, 0.5, and 1. In addition to the sectoral matching, data also need to be matched by country. For this purpose, the country with the firm's major operations (which may not be the country of the headquarters or the primary stock exchange listing) is used.

Table 4.17: Publications on regulatory practices

Study	Industries	Regions	Independent variables
Guasch (2001)	Electricity, telecommunications, railways, roads, water	Latin America	Type of price regulation
Espinasa (2001)	Electricity distribution	Latin America and Caribbean	Type of price regulation
Ros (2003)	Telecommunications	Latin America	Privatization, competition, existence of separated regulator, independence of regulator, existence of price cap regulation
Eurelectric (2004)	Electricity, gas	Western Europe	Existence of regulator, independence of regulator, staff number, budget size, recourse to other bodies, type of price regulation
Foster (2005)	Water	Latin America	Existence of regulator, independence of regulator, regulatory leadership
ITU (2007)	Telecommunications	Latin America and Caribbean	Type of price regulation
Millán (2007)	Electricity	Latin America and Caribbean	Type of price regulation
OECD (2008)	Utilities	Argentina, Australia, Brazil, Canada, Chile, New Zealand, Norway, U.K.	Existence of regulator, regulated sectors, institutional framework, market characteristics, policy context
Melling (2009)	Telecommunications	Worldwide	Existence of price cap regulation
KEMA Consulting (2010)	Gas	Eastern Europe	Existence of regulator, regulated services, responsibilities for tariffs, type of price regulation, regulatory period, elements of tariffs
Bel and Fageda (2010)	Airports	Western and Eastern Europe	Private ownership, type of price regulation
Müller and Niemeier (2011)	Airports	Western Europe, partially Eastern Europe	Degree of privatization, type of price regulation

Source: Kuntz (2011)

Table 4.18: Matching of sample and OECD infrastructure sectors

Firm sample segmentation	**OECD segmentation (8 sectors)**	**OECD segmentation (15 sectors)**	**OECD segmentation (18 sectors)**
Satellite	Telecommunications	Mobile services	Mobile services
Wireless	Telecommunications	Mobile services	Mobile services
Wireless - integrated	Telecommunications	Fixed-line (25%), Mobile services (75%)	Fixed-line (25%), Mobile services (75%)
Fixed-line	Telecommunications	Fixed-line network (50%), Fixed-line services (50%)	Fixed-line network (50%), Fixed-line services (50%)
Fixed-line - integrated	Telecommunications	Fixed-line (75%), Mobile services (25%)	Fixed-line (75%), Mobile services (25%)
Cable	Telecommunications	Fixed-line network (50%), Fixed-line services (50%)	Fixed-line network (50%), Fixed-line services (50%)
Airports	Air transportation	Air transport infrastructure	Air transport infrastructure
Ports	Water transportation	Water transport infrastructure	Water transport infrastructure
Highways	Road transportation	Road infrastructure	Road infrastructure
Railroads	Railway transportation	Railroad infrastructure	Railroad infrastructure (33%), Freight (33%), Passenger (33%)
Pipelines	Gas	Gas transmission	Gas transmission
Electricity - integrated	Electricity	Electricity generation (33%), transmission (33%), distribution (33%)	Electricity generation (33%), transmission (33%), distribution (33%)
Electricity - generation	Electricity	Electricity generation	Electricity generation
Electricity - transmission	Electricity	Electricity transmission	Electricity transmission
Electricity - distribution	Electricity	Electricity distribution and supply	Electricity distribution and supply
Water	Water	Water collection, purification and distribution	Water collection, purification and distribution
Gas	Gas	Gas distribution and supply	Gas distribution and supply
Multi - Electricity, Gas	Electricity (50%), Gas (50%)	Electricity integrated (50%), Gas distribution (50%)	Electricity integrated (50%), Gas distribution (50%)
Multi - Electricity, Gas, Water	Electricity (33%), Gas (33%), Water (33%)	Electricity integrated (33%), Gas distribution (33%), Water (33%)	Electricity integrated (33%), Gas distribution (33%), Water (33%)
Multi - Electricity, Water	Electricity (50%), Water (50%)	Electricity integrated (50%), Water (50%)	Electricity integrated (50%), Water (50%)
Multi - Gas, Water	Gas (50%), Water (50%)	Gas distribution (50%), Water (50%)	Gas distribution (50%), Water (50%)

Source: Author

4.5.4 Inflation and other macroeconomic data

The time series for inflation and GDP growth as well as USD exchange rates and long-range equity index returns are obtained from Global Financial Data (GFD). The GFD data are provided in a consistent manner across a long time series as disruptive macroeconomic events such as currency changes, revaluations, and sovereign defaults are corrected in a way as these external shocks would have impacted an investor. The availability of this kind of long-range and consistent data is of particular relevance for the inflation hedging analysis in chapter 7.

The GFD dataset covers 50 countries – including both emerging and developed countries – and spans from 1973 till 2009, covering 37 years.[31] The following list provides details on which data sources are employed by GFD for each time series:

- Local inflation: National consumer price index
- GDP growth: National real GDP data[32]
- U.S. Dollar exchange rate: Exchange rate from U.S. Dollar to local currency[33]
- Local equity: Total shareholder returns of a broad domestic index[34]

In cases, where more recent, but monthly interest rate, USD exchange rate, and local equity index return data are required (e.g. for some risk metrics as defined in section 5.2.1) Thomson Datastream is used to retrieve these time series, since GFD does not provide monthly data.[35] Table 8.5 in the appendix provides an overview of the used TDS mnemonics.

[31] The time series available on GFD reaches back to 1949, though the infrastructure data obtained through TDS only go back to 1973.

[32] The time series for Russia is adjusted to commence at the foundation of the Russian Federation.

[33] Neither interest payments nor costs of carrying are included. Black market rates are estimated during major disruptions by GFD.

[34] Most of the national indices are extended backwards by GFD by using older national indices. For Egypt the the return series is manually extended using the EGX100 of the Egypt Stock Exchange.

[35] In contrast, TDS does not provide consistent, long-range time series data for inflation, GDP growth, exchange rates, and equity returns.

Chapter 5

The Investment Risk Profile of Infrastructure

This chapter empirically investigates the investment risk profile of listed infrastructure relative to other public equities. After defining the risk metrics for corporate and market risk, the methodology for both the descriptive and the regression approach is presented. Next, the empirical results are provided along with various robustness tests. Finally, possible reasons for the idiosyncratic risk exposure of infrastructure are discussed and implications for both investment management and public policy are derived. This chapter follows Rothballer and Kaserer (2011) and Rothballer and Kaserer (2012b).

5.1 Motivation

Many investors' primary motivation to allocate funds to the infrastructure asset class is its supposed low risk exposure. Infrastructure is commonly associated with low market correlation and little corporate risk as detailed in section 3.1.1. The common arguments for the hypothesized low market risk include the essential good and the natural monopoly characteristic as well as the regulatory buffering effect. Investors also claim that infrastructure firms have stable, predictable and sustainable income streams and hence low firm-specific risks. Besides the previous arguments, the stability of the business environment is due to a lack of substitutes, little operational and strategic risks, and the low competitive pressure related to high entry barriers. In summary, the hypotheses of low market and firm-specific risk should imply lower total corporate risk relative to other industries.

However, empirical evidence corroborating these hypotheses is scarce. As reviewed in section 3.1.2, the initial empirical studies provide an inconclusive result regarding the riskiness of infrastructure investments. While several authors find that total corporate risk of infrastructure investments is on par with other industries, other authors present diverging evidence of lower risk exposure. Though most studies indicate that both listed and unlisted infrastructure indeed have modest market risk, the employed methodologies and samples often lack the statistical validity to allow a definite conclusion. However, a thorough understanding of the actual investment risk profile of infrastructure is critical to lessen the risks of this emerging investment strategy (Vanguard (2009)), and to address the global infrastructure gap of $71 trillion (OECD (2007)) by attracting more private investors to this asset class.

I contribute to the emerging body of literature on the infrastructure risk profile by analyzing both total and market risk in an integrated approach using a variety of robust metrics. I use a large, global sample across all infrastructure sectors to preclude a sample bias, and a statistically sound methodology to control for other risk factors. In the course of this chapter, I investigate the following two hypotheses H1.1 and H1.2 as introduced in section 3.1.3:

H1.1: Listed infrastructure firms have less corporate risk than other public equities

H1.2: Listed infrastructure firms have less market risk than other public equities

5.2 Methodology

5.2.1 Risk metrics

This section presents the risk metrics used in the descriptive and the regression analysis of the infrastructure risk profile. Metrics for both corporate and market risk are computed based on the data introduced in section 4.4.

Corporate risk Metrics for corporate risk (or total risk[1]) describe the riskiness of a stock from a stand-alone perspective. They implicitly assume that the investor is exposed to a single stock only, thus ignoring any diversification benefits that would arise in a portfolio context. Hence, they capture the full corporate risk including both systematic and idiosyncratic risk. Idiosyncratic risk can be attributed to factors specific to a company, such as the effects of management quality or the impact of competition, and is uncorrelated to other idiosyncratic risks or fluctuations in the economy. In contrast, systematic risk is correlated across firms and associated with variations of aggregate output.

The most commonly used measure for corporate risk is the standard deviation of returns δ_i. I also compute further moments of the return distribution $R_{i,t}$ as univariate risk measures for each company i: The mean $\bar{R}_i$, the skewness $Skew_i$, and the excess kurtosis $ExcessKurtosis_i$:

$$\bar{R}_i = \frac{1}{T}\sum_{t=1}^{T} R_{i,t} \tag{5.1}$$

$$\delta_i = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(R_{i,t} - \bar{R}_i)^2} \tag{5.2}$$

[1]Corporate risk and total risk are used interchangeably in this thesis.

$$Skew_i = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{R_{i,t}-\bar{R}_i}{\delta_i}\right)^3 \quad (5.3)$$

$$ExcessKurtosis_i = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{R_{i,t}-\bar{R}_i}{\delta_i}\right)^4 - 3 \quad (5.4)$$

In addition, I calculate alternative metrics for skewness and excess kurtosis, which are more robust to outliers (Kim and White (2004)):

$$Skew2_i = \frac{\hat{P}_{i,75}+\hat{P}_{i,25}-2\hat{P}_{i,50}}{\hat{P}_{i,75}-\hat{P}_{i,25}} \quad (5.5)$$

$$ExcessKurtosis2_i = \frac{\hat{P}_{i,87.5}-\hat{P}_{i,62.5}+\hat{P}_{i,37.5}-\hat{P}_{i,12.5}}{\hat{P}_{i,75}-\hat{P}_{i,25}} - 1.23 \quad (5.6)$$

where $\hat{P_{i,\alpha}}$ denotes the α-percentile of $R_{i,t}$.

As the infrastructure sample is plagued by a high share of illiquidly traded stocks, I also compute a liquidity-adjusted volatility according to Getmansky et al. (2004):

$$\delta_i^{Getmansky} = \frac{\delta_i}{\sqrt{h_i}} \quad (5.7)$$

where δ_i denotes the stock's conventional volatility defined as the standard deviation of returns and

$$h_i = \theta_{i,0}^2 + \theta_{i,1}^2 + ... + \theta_{i,k}^2 \quad (5.8)$$

where the θ_i are determined from the following return generating process with lagged local market returns $M_{i,t}$ using OLS estimation:[2]

$$R_{i,t} = \alpha_i + \beta_i(\theta_{i,0}M_{i,t} + \theta_{i,1}M_{i,t-1} + ... + \theta_{i,k}M_{i,t-k}) + \epsilon_{i,t} \tag{5.9}$$

and where the $\theta_{i,j}$ adhere to

$$1 = \theta_{i,0} + \theta_{i,1} + ... + \theta_{i,k} \tag{5.10}$$

All above univariate risk metrics are calculated based on local currency data and USD data, with the latter also incorporating currency risk.

Systematic risk While corporate risk metrics describe the risk on a standalone basis, systematic risk (or market risk[3]) metrics capture the risk a stock contributes to the portfolio of a well diversified investor. Modern portfolio theory based on Markowitz (1952) shows that idiosyncratic risk is diversified away when returns are not perfectly correlated leaving investors with exposure to systematic risk only. Systematic risk only relates to macroeconomic fluctuations and not to firm-specific events.

The Capital Asset Pricing Model (CAPM) of Sharpe (1964) and Lintner (1965) is the primary methodology to derive estimates for systematic risk. However, the CAPM has been challenged on both empirical and theoretical grounds. Early empirical studies, that test the CAPM directly, show that firms with high earnings-to-price ratios (Basu (1977)), low market capitalizations (Banz (1981)), high book-to-market ratios (Rosenberg et al. (1985)), and high leverage (Bhandari (1988)) as well as 'loser' and short-term momentum stocks[4] (DeBondt and Thaler (1985), Jegadeesh (1990)) tend to earn significantly higher returns than other stocks.[5] These findings contradict the central prediction of the CAPM as average returns should

[2] I use a lag of two months to fit the return process as in Getmansky et al. (2004), Aragon (2007), and Lahr and Herschke (2009).

[3] Market risk and systematic risk are used interchangeably in this thesis.

[4] 'Loser' stocks are characterized by poor returns over the past years and short-term momentum stocks by good performance over the previous few months.

[5] For a survey of the empirical results on this model, refer to Fama and French (2004).

only be affected by beta.[6] Further empirical critiques of the CAPM include the fact that actual return distributions do not comply with the normality assumption, and that the investment weights of the derived tangency portfolios are often negative. The CAPM is also challenged from a theoretical perspective, as it is based on expected utility theory, though Kahneman and Tversky (1979)'s prospect theory models human behavior more accurately. However, Levy (2010) derives a modified version of the CAPM, that cannot be rejected in a cumulative prospect theory framework. As long as ex-ante rather than ex-post parameters are employed in the CAPM tests, the empirical objections cannot be supported either. Despite the ongoing academic debate on whether CAPM is "dead or alive", the CAPM is dominantly used in practice (Bruner et al. (1998), Graham and Harvey (2001)). More specifically to infrastructure, it is also regularly utilized in regulatory proceedings (e.g. Oxera (2009), Network Economics Consulting Group (2003), NERA (1999)). For these reasons, I use the market model form of the Capital Asset Pricing Model to derive estimates for systematic risk:

$$R_{i,t} = \alpha_i + \beta_i M_{i,t} + \epsilon_{i,t} \tag{5.11}$$

where $R_{i,t}$ is the return of the respective company i in period t, $M_{i,t}$ the return of the corresponding market index of company i in period t, and β_i the sensitivity of the company's returns to market returns.[7] The above model is run with two different market index specifications. First, I use the respective company's home

[6]Based on their findings that book-to-market and size have the strongest relation to returns, Fama and French (1992) present the competing Fama-French 3-Factor model. However, their results are also objected due to a potential survivorship bias and the used beta estimation technique (Kothari et al. (1995)).

[7]There is a wide range of techniques to estimate betas empirically. Monthly return intervals are used since this is the standard approach in practice. Damodaran (1999) and Zimmermann (1997) show that the choice of the time period and the index can have a significant impact on the estimated betas. Thus, various approaches are employed to test the robustness across time and for different underlying indices. In contrast, the chosen regression technique (here: OLS) and the return calculation methodology (here: continuously compounded returns) do not significantly alter the estimation results (Zimmermann (1997)). Hence, no robustness tests are presented for these methodological choices.

country index[8] and local currency returns, thus assuming a local investor's point of view without international diversification (*Local Beta*). In this approach, beta is not impacted by currency risk and therefore represents a good proxy for systematic risk. The main drawback of using local indices is that they are sometimes biased by large index members and not representative, particularly in small or emerging countries (Damodaran (1999)). Therefore, I use a second specification with the MSCI World index[9] and USD returns, implying an international investor's point of view (*World Beta*). Estimates of beta based on this approach do not only incorporate financial and business risk but also currency risk potentially disguising the true, fundamental risk characteristics. As discussed in the international asset pricing literature (Solnik (1974), Stulz (1981), Adler and Dumas (1983), Dumas (1995)), the price of currency risk is significantly different from zero, thus implying a model misspecification if currency risk is not modeled as a risk factor. Therefore, I run a third, extended specification explicitly including a currency risk factor $Curr_{i,t}$. The coefficient of the currency risk factor γ_i is able to capture the currency risk, thus effectively producing unbiased beta estimates β_i (*International Beta*):

$$R_{i,t} = \alpha_i + \beta_i M_{i,t} + \gamma_i Curr_{i,t} + \epsilon_{i,t} \tag{5.12}$$

$Curr_{i,t}$ is the continuously compounded monthly excess return in period t on short-term deposits denominated in the local currency of the respective company i and measured in the reference currency USD:

$$Curr_{i,t} = ln\left(\left(IR_{i,t}^{local} - IR_{i,t}^{USD} + 1\right)\left(\frac{ER_{i,t}}{ER_{i,t-1}}\right)\right) \tag{5.13}$$

where $IR_{i,t}^{local}$ ($IR_{i,t}^{USD}$) is the average three-month interbank interest rate in period t in the home country of company i in local currency (or the U.S. interest rate in

[8] I mostly use the respective MSCI country index. Refer to Table 8.5 in the appendix for the details on the used country indices.

[9] I use the MSCI World instead of the MSCI All Country World as it has a longer time series available. This implies that the value-weighted average beta of all firms is not exactly 1.

USD), and $ER_{i,t}$ is the exchange rate between the local currency and USD expressed in quantity quotation, i.e. using the local currency as unit currency and USD as price currency.[10] Note, that for stocks traded in USD, equation (5.13) sets $Curr_{i,t}$ to zero.

When stocks are subject to infrequent trading, beta estimates from the conventional market model regressions tend to be deflated and thus biased. I apply the aggregated coefficients method suggested by Dimson (1979) for calculating liquidity-adjusted *Dimson Betas* by running a multiple regression of observed returns against contemporaneous and preceding market returns:[11]

$$R_{i,t} = \alpha_i + \beta_{i,0} M_{i,t} + \beta_{i,1} M_{i,t-1} + \beta_{i,2} M_{i,t-2} + ... + \beta_{i,k} M_{i,t-k} + \epsilon_{i,t} \qquad (5.14)$$

$$\beta_i^{Dimson} = \beta_{i,0} + \beta_{i,1} + \beta_{i,2} + ... + \beta_{i,k} \qquad (5.15)$$

Business risk All above beta estimates incorporate both financial and business risk. Business risk is the risk associated with the unique circumstances of a particular company and its business model, assuming the company would not be leveraged. Financial risk is the additional risk shareholders have to bear when a company uses debt in addition to equity. Excessive leverage and financial risk could potentially disguise the fundamentally low business risk of infrastructure. Therefore, *Asset Betas* are derived as proxies for business risk for all sample companies using Hamada (1972)'s deleveraging approach:

$$\beta_i^u = \frac{\beta_i}{1 + (1 - Tax_i)\ Leverage_{i,t}} \qquad (5.16)$$

where β_i is the firm i's levered (equity) and β_i^u the unlevered (asset) beta, Tax_i the corporate tax rate[12] and $Leverage_{i,t}$ the ratio of the book value of total debt

[10] Interest rates and exchange rates are retrieved from TDS as explained in section 4.5.4. The respective TDS codes are provided in Table 8.5 in the appendix.

[11] Analogous to the Getmansky volatility, I use a lag of two months to fit the return process as in Getmansky et al. (2004), Aragon (2007), and Lahr and Herschke (2009).

[12] The corporate tax rate is assumed 30% for all firms in the sample.

to the market value of equity.

Idiosyncratic risk I compute the idiosyncratic volatility δ_i^{idio} as the difference between total and market risk:

$$\delta_i^{idio} = \sqrt{(\delta_i)^2 - (\beta_i)^2(\delta_i^{market})^2} \tag{5.17}$$

where δ_i is the volatility of company i, β_i the beta estimate against the corresponding market index for company i, and δ_i^{market} the volatility of the same market index.

Accounting-based risk metrics Similar to the return data based risk metrics, both univariate and bivariate accounting risk metrics are computed. To proxy corporate risk, each company's sales volatility and EBIT margin volatility are calculated as:

$$SalesVola_i = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(ln\left(\frac{Sales_{i,t}}{Sales_{i,t-1}}\right) - E\left(ln\frac{Sales_{i,t}}{Sales_{i,t-1}}\right)\right)^2} \tag{5.18}$$

$$EbitMarginVola_i = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{EBIT_{i,t}}{Sales_{i,t}} - E\left(\frac{EBIT_{i,t}}{Sales_{i,t}}\right)\right)^2} \tag{5.19}$$

where $EBIT_{i,t}$ and $Sales_{i,t}$ are the earnings before interest and tax and the sales of company i in time period t, and E denotes the expected value operator.

Following Cohen et al. (2009), I compute the following accounting betas as measures for systematic risk:

$$ln(ROA_{i,t} + 1) = \alpha_i + \beta_i^{acc} ln(ROA_{i,t}^{market} + 1) + \epsilon_{i,t} \tag{5.20}$$

where $ROA_{i,t}$ is the return on assets (EBIT divided by assets) of the respective company i in period t, $ROA_{i,t}^{market}$ the equally (or value) weighted return on assets among all MSCI sample companies in period t, and β_i^{acc} the sensitivity of the company's ROA to the market ROA. An analogous procedure is applied to compute accounting betas using returns on equity $ROE_{i,t}$ (net profit divided by book value of equity).

5.2.2 Descriptive approach

In the descriptive analysis in sections 5.3.1 through 5.3.4, the risk characteristics of infrastructure are directly compared to MSCI firms without controlling for other risk factors. Using the metrics for total and market risk, I provide medians for the infrastructure sample clustered by (sub)sectors and compare it to the benchmark derived from the reference sample. Two-tailed Mann-Whitney rank-sum tests (Mann and Whitney (1947)) are employed to test whether the respective risk metric's distribution in the infrastructure or in any subsample is statistically different from the MSCI sample – either confirming or contradicting H1.1 and H1.2. The Mann-Whitney U-test is applied instead of the t-test because of the non-normal distribution of most computed risk metrics. As a robustness test, I analyze all risk metrics for a reduced sample as well as accounting risk metrics (sections 5.3.3 and 5.3.4). The analysis includes all 1,458 infrastructure firms from 71 countries as described in section 4.3. For the descriptive analysis the maximum available time series for each company is used, potentially ranging from January 1975 to December 2009, i.e. covering up to 35 years. Robustness tests are provided for shorter time series from 1995-2009 (15 years) and 2005-2009 (5 years) with a correspondingly different sample size.

5.2.3 Regression model

Since the descriptive analysis does not control for confounding risk factors, the hypotheses H1.1 and H1.2 are also tested in a regression model. This approach ascertains that any resulting differences in corporate or systematic risk are due to the infrastructure characteristic and not caused by other company features. In the regression, I explicitly control for various factors that are not correlated with infrastructure but impact risk such as firm size, growth, financial leverage, dividends, trading liquidity, profitability and book-to-market (Fama and French (1992), Harvey and Siddique (2004), Beaver et al. (1970), Melicher and Rush (1974), Chandy and Davidson (1986)). In addition, I use a dummy for emerging market stocks and mark all infrastructure firms with an infrastructure, sector, or subsector dummy. Table 5.1 gives an overview of the used regressors and their respective definitions.

Table 5.1: Definition of regressors

Regressor	Definition
$ln\_FirmValue_{i,t}$	Natural logarithm of the market value of equity plus the book value of debt
$SalesGrowth_{i,t}$	Continuously compounded annual growth rate of sales
$ln\_Leverage_{i,t}$	Natural logarithm of the book value of total debt divided by the market value of equity
$DivPayout\_D_{i,t}$	Dummy that is 1 if the firm paid dividends in any of the 5 years, otherwise 0
$DivPayout_{i,t}$	Ratio of dividends per share to earnings per share
$TradCont_{i,t}$	Percentage of months in the respective time-series with non-zero returns
$ln\_RelTradVol_{i,t}$	Natural logarithm of number of shares traded for a stock divided by total number of shares
$EP\_D_{i,t}$	Dummy that is 1 if earnings are negative in any year of the 5-year period, otherwise 0
$EarningsPrice_{i,t}$	Earnings per share divided by closing price if earnings are positive, otherwise 0
$BookMarket_{i,t}$	Balance sheet value of ordinary equity divided by market value of ordinary equity
$Emerging\_D_i$	Dummy that is 1 if the firm is from an emerging market as defined by the MSCI index classification, otherwise 0

Source: Rothballer and Kaserer (2012b)

As some of the control variables are not available for all firms the sample size is reduced in comparison to the previous descriptive analysis. To increase the number of observations in the regressions, I pool three cross-sections of the sample. Each cross-section contains the averaged data of a five year period without overlap (1995-1999, 2000-2004, 2005-2009).[13] The later cross-sections contain more observations as the infrastructure sample is increasing over time due to continuous privatization activity and improving data availability on TDS.

The previously derived risk metrics for total, market, and idiosyncratic risk are

[13]A panel model is not applied as serial correlation can be considered negligible. There is a maximum of three observations per company, all data are computed from non-overlapping intervals, and for more than 1,000 companies data are available for just one or two 5-year periods. Table 5.8 provides the estimation results for each individual 5-year cross-section confirming the results of the pooled OLS.

used as dependent variables. The regression equations are estimated using ordinary least squares with robust standard errors to address heteroscedasticity. Across all equations the variance inflation factors are smaller than 3, indicating that there is no presence of multicollinearity.

5.3 Empirical results

5.3.1 Descriptive analysis of corporate risk

The results of the descriptive analysis of corporate risk based on local currency returns are displayed in Table 5.2 (using the maximum time series of up to 35 years for each sample firm). Mean returns to infrastructure (8.4%) are significantly lower than MSCI returns (12.2%), which is in line with the conventional view that the lower risk of infrastructure entails lower returns. Though this comparison of relative performance neglects the differences in survivorship bias and time horizons in both samples[14] the analysis of Wörner et al. (2011) using the same sample shows that the returns of infrastructure are indeed lower than for MSCI firms for the five (4% vs. 6%), ten (5% vs. 9%), and 15 year (7% vs. 10%) periods until 2010. The decomposition of total shareholder returns (TSR) into sales growth, margin change, multiple change, and dividend yield shows that this difference can be explained by lower sales growth among infrastructure relative to MSCI firms. However, the relative value creation profile of both samples is similar as sales growth is the main TSR driver.[15] Hence, it can be concluded that infrastructure has lower returns, but a similar value creation profile in comparison to non-infrastructure.

Contrary to popular perception, the volatility in the infrastructure sample is not significantly lower than in the MSCI sample contradicting H1.1. Indeed, it is slightly higher with 40.6% as opposed to 38.3%. While this difference is not significant,

[14]Survivorship bias is stronger in the MSCI sample as bad performers and bankrupt firms are regularly excluded from the index. Moreover, the lengths of the stocks' individual time series differ in both samples, as they are not matched through index chaining, potentially distorting the results.

[15]As expected, the dividend contribution is slightly higher for infrastructure firms than for MSCI firms (3% average dividend yield vs. 2%).

some infrastructure sectors even have a significantly higher median volatility than MSCI stocks. This is particularly evident in the telecom subsectors with volatilities of around 50% and among some transport subsectors such as pipelines and ports. However, the median volatility among utilities (32.6%) is significantly lower – driven by water, gas and multi utilities – though the absolute difference is small. Besides the strong differences between telecom, transport, and utilities even within sectors stark differences can be observed: Volatility for pipelines is around 20%-points higher than for railroads, and electricity utilities surpass multi utilities to a similar degree. These results also hold for the illiquidity-adjusted Getmansky et al. (2004) volatility, which is 39% for both the infrastructure and the MSCI sample.

Infrastructure exhibits less negative skewness (-0.01) than MSCI stocks (-0.17) indicating that infrastructure has longer right tails in its probability density function and thus an increased likelihood of pleasant surprises. This might be due to the monopolistic market position of infrastructure firms that potentially causes supply bottlenecks. Despite being significantly lower across most subsectors, the absolute difference of skewness is low. However, the difference seems to be partly caused by outliers as the robust skewness metrics indicate that differences in skewness are less pronounced. While skewness measures the asymmetry of the return distribution, kurtosis measures its 'peakedness' relative to a normal distribution. The excess kurtosis of infrastructure stocks (0.06) is higher than that found in MSCI stocks (-0.75), indicating that infrastructure return distributions have a higher proportion of extreme events. Excess kurtosis in comparison to the MSCI can be observed in most infrastructure subsectors, though absolute differences are again small. The fatter tails in infrastructure returns can be explained by the exposure to external shocks in the long term due to its sunk-cost character, the high asset specificity, and the location boundedness. Positive shocks are driven by the inelasticity of infrastructure supply and the monopolistic market positions. Negative shocks include changing geographic infrastructure requirements (e.g. change of trade flows, population patterns), technology innovations (e.g. new energy generation technology, new transport modes such as high speed rail) or new regulations (e.g. subsidies,

Table 5.2: Corporate risk metrics

	Return	**Volatility**	**Getmansky-Volatility**	**Skewness**	**Skewness 2**	**Excess Kurtosis**	**Excess Kurtosis 2**
	Med, 35yr, L in %	*Med, 35yr, L in %*	*Med, 35yr, L in %*	*Med, 35yr, L*	*Med, 35yr, L*	*Med, 35yr, L*	*Med, 35yr, L*
MSCI	12.2	38.3	39.2	-0.17	0.02	-0.75	0.13
Infrastructure	8.4 ***	40.6	39.0	-0.01 ***	0.04 ***	0.06 ***	0.23 ***
Telecommunication	3.4 ***	50.9 ***	50.2 ***	-0.06 ***	0.01 *	-0.23 ***	0.22 ***
Transport	5.9 ***	39.6	41.3	-0.07 ***	0.04 **	-0.30 **	0.23 ***
Utilities	10.2 ***	32.7 ***	33.9 ***	0.04 ***	0.05 ***	0.27 ***	0.24 ***
Satellite	-6.7 ***	57.5 ***	68.5 ***	-0.10	-0.01	-0.24	0.26 **
Wireless	5.3 ***	49.1 ***	44.5 ***	-0.05 **	0.02	-0.59 **	0.20 ***
Fixed-line	3.5 ***	54.7 ***	54.0 ***	-0.08	0.01	0.05 ***	0.26 ***
Cable	3.7 ***	48.9 ***	56.7 ***	0.00 **	-0.01	-0.59	0.13
Airports	5.8 ***	35.7 *	38.6	-0.28 *	0.09	0.38	0.13
Ports	7.0 ***	45.6 ***	45.3 ***	0.05 **	0.03	-0.52	0.26 ***
Highways	7.2 ***	38.4	38.4	-0.09	0.02	-0.99	0.19 *
Railroads	5.6 ***	30.2 ***	31.2 ***	0.06 ***	0.04 *	0.51 ***	0.24 ***
Pipelines	6.2 ***	51.2 ***	55.0 ***	-0.10	0.04	-0.28	0.33 ***
Electricity	9.7 ***	42.3	39.7	0.01 ***	0.07 ***	0.21 ***	0.28 ***
Water	10.9 **	30.1 ***	31.4 ***	0.20 ***	-0.02	-0.27 *	0.17 ***
Gas	11.4 *	27.7 ***	28.4 ***	0.14 ***	0.03 *	0.34 ***	0.23 ***
Multi	11.0 ***	22.1 ***	22.7 ***	-0.10 **	0.03	0.47 ***	0.17 ***

Note: This table is based on the full sample of 1,458 infrastructure and 2,079 MSCI firms. *Med (Avg)* indicates that the reported figure is the median (average) of the respective subsample distribution; *L ($)* indicates that the results are based on local (USD) currency data; *35yr (15yr, 5yr)* indicates that for each firm the maximum time series of up to 35 (15, 5) years is used for the computation; ***, ** and * indicate that the distribution of the respective subsample is statistically different from the MSCI reference sample at the 1%, the 5%, and the 10% levels, respectively, using a two-tailed Mann-Whitney test.
Source: Rothballer and Kaserer (2011)

carbon caps). As these risks only materialize over a long time horizon when structural breaks occur they are only faintly visible in the sample. Notwithstanding, the excess kurtosis could also be caused by trading illiquidity as new information is not immediately reflected in stock prices when trading occurs infrequently.

Judging from the descriptive analysis of the corporate risk metrics, I conclude that infrastructure overall does not exhibit a substantially different risk profile in comparison to the general stock market. The most surprising result is the fact that volatility of infrastructure stocks is not significantly lower than in MSCI stocks, contradicting H1.1. The second striking finding is the significant variance of risk profiles across infrastructure sectors. Note, that these results are neither sensitive to the currency nor to the reported summary statistic and chosen timeframe. Using USD data instead of local currency returns yields similar results – with volatilities being slightly higher due to the additional currency risk as shown in Table 8.6 in the appendix. Similar results are also obtained when analyzing means instead of medians (Table 8.7) and when analyzing a 15- or 5-years instead of a 35-years time series (Table 8.8 and Table 8.9).

5.3.2 Descriptive analysis of systematic risk

The results of the descriptive analysis of systematic risk are displayed in Table 5.3. They suggest that infrastructure has significantly less systematic risk than non-infrastructure which is in accordance with H1.2. The median of local betas for infrastructure is 0.60 and 0.98 for MSCI stocks. The slightly lower spread when using world betas (0.68 vs. 1.03) reflects the higher currency risk exposure in the infrastructure sample. Applying the international CAPM almost perfectly mirrors the results from the local beta estimates (0.59 vs. 0.98), demonstrating its efficacy in capturing currency risk. A bias from trading illiquidity can be ruled out as the significant difference between the two samples is also confirmed by the Dimson betas. The medians for both groups are slightly higher (0.67 and 1.02 for Local Dimson Beta; 0.79 and 1.11 for World Dimson Beta) but the relative difference remains constant and significant. When accounting for leverage, I find that infrastructure is still significantly less risky than non-infrastructure with a local asset beta of 0.37 as opposed to 0.69 for non-infrastructure. The relative difference remains similar as the average leverage in both samples is close: 1.35 in the MSCI sample and 1.29 in the infrastructure sample (corresponding to a debt ratio of about 57%). Excessive leverage as it has been observed in the U.K. water and electricity sectors (Bucks (2003)) seems not to materialize across the board. The observed gearing ratios in this sample of listed infrastructure firms are broadly in line with those typically witnessed for project finance deals and (unlisted) infrastructure assets, though at the lower end.[16] For example, Colonial First State (2006a) reports that typical gearing (debt to enterprise value) ratios are 30-50% for ports, 40-70% for airports, 30-80% for toll-roads, 50-80% for electricity transmission and distribution, and 60-90% for water. The relatively low observed leverage ratios in my listed infrastructure sample may be caused by more effective corporate governance for unlisted assets, the additional velocity of capital markets, and the extensive use of project finance effectively reducing their on-balance-sheet debt burden.

Similar to the findings from the analysis of corporate risk, the differences in systematic risk between infrastructure sectors is distinctive. None of the telecommunication subsectors' equity betas – they mostly range between 0.9 and 1.1 – is significantly lower than the corresponding estimate for the MSCI sample. In contrast, betas for transport and utilities are significantly lower across all subsectors and metrics. Median betas for transport fall mostly in the range of 0.6 to 0.8, while utility betas are even lower ranging between 0.4 and 0.6. The different risk profiles are largely matched by the typical return expectations of investors. Investor surveys of Deloitte (2011), Weber (2009), and JP Morgan Asset Management (2010) show that Internal Rates of Returns (IRR) expectations are highest for airport, ports, and telecoms, and lowest for water, and other regulated utilities. Besides the differences between sectors, there are also significant differences within sectors. The local

[16] A similar phenomenon is observed for real estate: REITs (Real Estate Investment Trust) typically bear significantly lower financial debt than what is commonly used for unlisted real estate investments.

Table 5.3: Systematic risk metrics

	Local Beta	World Beta	International Beta	Local Dimson Beta	World Dimson Beta	Local Asset Beta	World Asset Beta
	Med, 35yr, L	*Med, 35yr, $*	*Med, 35yr, $*	*Med, 35yr, L*	*Med, 35yr, $*	*Med, 35yr, L*	*Med, 35yr, $*
MSCI	0.98	1.03	0.98	1.02	1.11	0.69	0.73
Infrastructure	0.60 ***	0.68 ***	0.59 ***	0.67 ***	0.79 ***	0.37 ***	0.45 ***
Telecommunication	0.93 *	1.09	1.02	1.04	1.28 ***	0.56 ***	0.62 ***
Transport	0.61 ***	0.73 ***	0.58 ***	0.69 ***	0.77 ***	0.38 ***	0.45 ***
Utilities	0.46 ***	0.50 ***	0.42 ***	0.49 ***	0.52 ***	0.30 ***	0.34 ***
Satellite	0.95	1.14	1.10	1.12	1.36 **	0.60	0.65
Wireless	0.93 *	1.04	0.98	0.99	1.34 ***	0.63 *	0.67
Fixed-line	0.96	1.13 *	1.06	1.01	1.23 ***	0.52 ***	0.60 ***
Cable	0.90	1.01	1.01	1.06	1.26	0.48 ***	0.55 ***
Airports	0.74 ***	0.94	0.81	0.93 *	1.18	0.49 ***	0.65
Ports	0.61 ***	0.72 ***	0.49 ***	0.70 ***	0.71 ***	0.49 ***	0.54 ***
Highways	0.56 ***	0.68 ***	0.56 ***	0.53 ***	0.61 ***	0.31 ***	0.32 ***
Railroads	0.57 ***	0.62 ***	0.45 ***	0.56 ***	0.54 ***	0.33 ***	0.43 ***
Pipelines	0.57 ***	0.86 ***	0.66 ***	0.88	1.18	0.27 ***	0.45 ***
Electricity	0.49 ***	0.55 ***	0.47 ***	0.55 ***	0.64 ***	0.32 ***	0.40 ***
Water	0.43 ***	0.39 ***	0.36 ***	0.47 ***	0.45 ***	0.28 ***	0.27 ***
Gas	0.43 ***	0.50 ***	0.43 ***	0.46 ***	0.49 ***	0.28 ***	0.32 ***
Multi	0.39 ***	0.40 ***	0.38 ***	0.35 ***	0.34 ***	0.26 ***	0.27 ***

Note: This table is based on a sample of 1,458 (1,460) infrastructure and 2,079 (2,073) MSCI firms for local currency (for USD) based data, except for asset beta where the number of datapoints is reduced due to the lower availability of leverage data. *Med (Avg)* indicates that the reported figure is the median (average) of the respective subsample distribution; *L ($)* indicates that the results are based on local (USD) currency data; *35yr (15yr, 5yr)* indicates that for each firm the maximum time series of up to 35 (15, 5) years is used for the computation; ***, ** and * indicate that the distribution of the respective subsample is statistically different from the MSCI reference sample at the 1%, the 5%, and the 10% levels, respectively, using a two-tailed Mann-Whitney test.
Source: Rothballer and Kaserer (2011)

betas of airports (0.74) and ports (0.61) demonstrate their larger exposure to the economic cycle in comparison to highways (0.56) and railroads (0.57), since global air traffic and port exports react much more sensitively to macroeconomic changes than mostly local and regional road and rail passenger traffic. But even within sub-sectors stark differences are visible. Ports that are focused on bulk cargo (e.g. coal, iron ore, crops, oil & gas) have a median local beta of 0.39, whereas container ports display a beta of 1.00 (Wörner et al. (2011)). This may be explained by the fact that bulk cargo constitutes a natural monopoly as transshipment is not feasible and other modes are less competitive, and demand for bulk commodities is less volatile than for discretionary consumer goods shipped by containers. Similarly, large international hub airports have an average beta of 0.99 while regional airports that are focused on point-to-point traffic have an average beta of 0.53 (Wörner et al. (2011)), since the latter's passenger numbers are less exposed to the economy and less affected by competition from competing hubs.

In summary, I conclude that both the market and the business risk of infrastructure is significantly lower in comparison to the market average, confirming H1.2. The lower systematic risk exposure therefore reflects the lower realized returns in infrastructure as observed in section 5.3.1. Again, the significant differences in the risk profiles across infrastructure sectors is noteworthy. These results are robust to the chosen summary statistic and timeframe. Similar results are obtained when analyzing means instead of medians (Table 8.7) and when analyzing a 15- or 5-years instead of a 35-years time series (Table 8.8 and Table 8.9).

5.3.3 Robustness test with reduced sample

The constituents of the infrastructure and MSCI samples are not homogeneous with regard to all firm characteristics as described in section 4.3. Trading illiquidity is less present among MSCI stocks and they also tend to be larger on average, as the MSCI index accession criteria screen for large, liquidly traded stocks. All MSCI firms were active as of December 2009 while some of the infrastructure stocks became inactive due to insolvencies, delistings or mergers, causing a relative difference in survivorship bias in the two samples. Because of this heterogeneity both samples are filtered by applying the following criteria:[17]

- Active companies: Exclusion of stocks that are inactive as of the variable $CompanyStatus_i$ or for which no stock trade occurred over the past consecutive 12 months.
- Liquidly traded companies: Exclusion of stocks with a relative trading volume $RelTradVol_{i,t} < 0.4\%$ or a bid-ask-spread $BidAskSpread_{i,t} > 20\%$.[18] In addition, stocks with trade discontinuities (i.e. zero returns) in $\geq 20\%$ of the observations (i.e. $TradCont_{i,t} < 80\%$) in its respective return time series are excluded.
- Large companies: Exclusion of stocks with a market capitalization $EquityMV_{i,t} <$ \$300 million.[19]

After applying these filters, the number of infrastructure firms in the sample drops from 1,458 to 675, while the number of MSCI firms only drops from 2,079 to 2,002. Repeating the above analysis for the refined samples yields the results in Table 5.4, reaffirming the emerging picture of infrastructure as highly heterogeneous asset class with a corporate risk comparable to other industries (contradicting H1.1), but significantly lower systematic risk (confirming H1.2). Volatility of infrastructure stocks (38.2%) is still not significantly different from MSCI stocks (37.9%), despite the highly significant, lower systematic risk with a local beta of 0.68 versus 0.98. The strong variation in risk profiles among infrastructure sectors also persists − telecommunication being the riskiest sector, both in terms of total and market risk, and utilities being the sector with lowest risk across all metrics. But even for

[17]The geographic bias towards emerging markets in the infrastructure sample, is automatically lessened through the exclusion of illiquidly traded and small firms (which are mostly emerging market based).

[18]Refer to section 4.4.3 for the definition of relative trading volume and bid-ask-spread. Both figures are calculated using averages of monthly data across the whole time series of each firm. These cut-off values are also used by other authors such as Bilo et al. (2005) and Lahr and Herschke (2009).

[19]The minimum market capitalization in the MSCI sample as of 31 December 2009 is \$331 million.

utilities, the difference in volatility in comparison to MSCI stocks is small, despite the significantly lower systematic risk with a local beta of 0.55.

Table 5.4: Corporate and systematic risk metrics for reduced sample

	Volatility		**Getmansky-Volatility**		**Local Beta**		**Local Dimson Beta**	
	Med, 35yr, L in %		*Med, 35yr, L in %*		*Med, 35yr, L*		*Med, 35yr, L*	
MSCI	37.9		38.9		0.98		1.02	
Infrastructure	38.2	**	36.8	***	0.68	***	0.69	***
Telecommunication	41.9	***	38.3		0.93	**	0.92	***
Transport	37.3	**	37.4	*	0.62	***	0.69	***
Utilities	33.9	***	34.7	***	0.55	***	0.57	***
Satellite	39.1		53.3		0.82		1.05	
Wireless	41.7	**	38.3		0.92	**	0.92	***
Fixed-line	42.7	**	37.9		0.97		0.85	**
Cable	44.4		40.3		0.91		0.92	
Airports	37.4		39.9		0.74	***	0.94	
Ports	45.4		41.4		0.57	***	0.63	***
Highways	37.2		38.1		0.52	***	0.45	***
Railroads	27.6	***	26.8	***	0.68	***	0.70	***
Pipelines	30.4	**	35.9		0.67	**	0.67	*
Electricity	42.7		40.4		0.60	***	0.63	***
Water	32.3	**	35.1	**	0.42	***	0.46	***
Gas	25.4	***	24.5	***	0.60	***	0.56	***
Multi	23.8	***	23.3	***	0.50	***	0.49	***

Note: This table is based on a sample of 675 infrastructure and 2,002 MSCI firms. *Med (Avg)* indicates that the reported figure is the median (average) of the respective subsample distribution; *L ($)* indicates that the results are based on local (USD) currency data; *35yr (15yr, 5yr)* indicates that for each firm the maximum time series of up to 35 (15, 5) years is used for the computation; ***, ** and * indicate that the distribution of the respective subsample is statistically different from the MSCI reference sample at the 1%, the 5%, and the 10% levels, respectively, using a two-tailed Mann-Whitney test.
Source: Rothballer and Kaserer (2011)

5.3.4 Robustness test with accounting data

The surprisingly high level of volatility of infrastructure deserves further investigation. To preclude a systematic bias in the previous findings that are based on return data, I revert to an additional data source, namely accounting data. As accounting data are connected to stock price data through the valuation process, the same hypothesized risk characteristics of infrastructure should also be visible in accounting-based risk metrics. Analogous to return data, both univariate (company's sales volatility, EBIT margin volatility) and bivariate accounting risk metrics (accounting beta) are analyzed, as defined in section 5.2.1.

Table 5.5: Corporate and systematic risk metrics using accounting data

	Sales Volatility		**EBIT margin volatility**		**ROA beta (equal)**		**ROE beta (equal)**	
	Med, 35yr, L in %		*Med, 35yr, L in %*		*Avg, 35yr, L*		*Avg, 35yr, L*	
MSCI	17.0		5.7		0.93		0.44	
Infrastructure	15.9		9.0	***	0.77	***	0.31	***
Telecommunication	19.6	***	14.3	***	1.73		0.66	
Transport	14.6		9.1	***	0.48	***	0.30	***
Utilities	14.8	***	7.3	***	0.38	***	0.16	***
Satellite	27.8	**	26.6	***	1.42		0.30	**
Wireless	17.7		13.9	***	1.37		0.95	**
Fixed-line	20.0	*	13.1	***	2.00		0.37	
Cable	16.7		15.8	***	2.04	*	1.01	
Airports	9.0	***	8.1	*	0.43	**	-0.18	***
Ports	15.0		7.3		0.25	***	0.08	***
Highways	16.2		11.5	***	0.60		0.49	**
Railroads	9.6	***	6.9		0.54	**	0.60	
Pipelines	42.1	***	11.6	**	0.61		0.31	
Electricity	15.4		8.5	***	0.45	***	0.22	***
Water	11.8	**	8.5	***	-0.28	***	-0.18	***
Gas	14.5	**	4.1	***	0.47	***	0.28	***
Multi	15.0		6.2		0.42	***	0.04	***

Note: This table is based on a sample of 871, 909, 1,079, and 1,021 infrastructure and 1,731, 1,756, 1,896, and 1,021 MSCI firms (in this order for the different datatypes). *Med (Avg)* indicates that the reported figure is the median (average) of the respective subsample distribution; *L ($)* indicates that the results are based on local (USD) currency data; *35yr (15yr, 5yr)* indicates that for each firm the maximum time series of up to 35 (15, 5) years is used for the computation; ***, ** and * indicate that the distribution of the respective subsample is statistically different from the MSCI reference sample at the 1%, the 5%, and the 10% levels, respectively, using a two-tailed Mann-Whitney test.
Source: Rothballer and Kaserer (2011)

The accounting risk metrics in Table 5.5 reinforce the conclusions drawn from the analysis of return data. While the total corporate risk of infrastructure firms is not significantly lower than in other industries (contradicting H1.1), systematic risk is significantly lower (confirming H1.2). Hence, the accounting data based results underline the reliability of the stock market data, and therefore address the potential critique discussed in section 4.1.1 about the use of stock market returns of listed firms.

Sales volatility for infrastructure firms (15.9%) is only slightly lower than for MSCI firms (17.0%), though not being significant. The often acclaimed characteristic of stable revenues caused by inelastic consumer demand, monopolistic market positions and regulated prices seem not to materialize. Even utilities' sales volatility is only 2%-points below MSCI firms, though being significant. When reverting to profitability data, infrastructure emerges as even riskier in comparison to its benchmarks. EBIT margin volatility of infrastructure firms (9.0%) is significantly higher than for MSCI firms (5.7%). Interestingly, this does not only hold for telecommunication but also for transport and utilities and across most of the subsectors. The fact that infrastructure sales volatility is comparable to other industries while its EBIT volatility is significantly higher can be attributed to the high share of fixed costs, i.e. high operating leverage rendering infrastructure vulnerable to sales declines. The high fixed costs are driven by depreciation for capital-intensive assets, asset maintenance costs, and operational costs to assure asset availability that are unrelated to output. The high share of long-term contracts and the lack of short-term pricing flexibility due to regulation also contribute to the high EBIT variability among infrastructure firms. Likewise to return betas, the accounting betas for infrastructure overall (0.77 for equally-weighted ROA-based beta) as well as for transport (0.48) and utilities (0.38) are significantly lower than for MSCI firms (0.93). This finding is robust to the underlying performance metric (return to equity or return to assets) and the calculation methodology for the market average (value or equal weighting).[20]

[20]In contrast to expectation, the average ROE accounting beta for MSCI firms is not close to 1. This is because firm observations are regressed against a market time series with a varying number of constituents and because of the overall low number of time series observations in the regression.

5.3.5 Regression analysis

The descriptive analyses in the previous sections reveal that infrastructure stocks have a volatility similar to the market average while showing a significantly lower market risk. In order to ascertain that these findings are due to the infrastructure characteristic and not caused by confounding risk factors, the hypotheses H1.1 and H1.2 are tested in a regression approach that controls for firm size, growth, financial leverage, dividends, trading liquidity, profitability and book-to-market as detailed in section 5.2.3. In addition to the risk metrics for total and market risk, idiosyncratic volatility is employed as dependent variable, as the preliminary finding suggests that infrastructure is particularly exposed to idiosyncratic risks.

The regression results in Table 5.6 corroborate the emerging finding that infrastructure is an 'average volatility, low beta business'. Though the infrastructure dummy in the volatility regression is significantly negative, the absolute difference in volatility versus MSCI firms is only 3%-points. There is some variation among infrastructure sectors, with telecommunication having a 5%-points higher volatility and each transport and utilities having a 6%-points lower volatility. In contrast, the regression analysis strongly confirms H1.2 as the market risk of infrastructure is significantly lower (infrastructure dummy coefficient of -0.25). However, low systematic risk is not a feature that can be attributed to all infrastructure sectors. Telecom companies' systematic risk is not significantly different from the market average while the market risk for transport (dummy coefficient of -0.26) and for utilities (dummy coefficient of -0.38) is significantly lower. In contrast to the theoretical reasoning, the idiosyncratic volatility of infrastructure is not significantly different from the benchmark firms. Despite their quasi-monopolistic market positions and low operational and innovation risks, infrastructure firms seem to be exposed to the same level of idiosyncratic risks as MSCI firms. Again, there is some variation among sectors with telecom having a positive dummy coefficient of 5% and both transport and utilities showing slightly negative coefficients of -3%. Consequently, the share of idiosyncratic risk is significantly higher for infrastructure firms. Overall, the market risk of infrastructure firms is lower while idiosyncratic risk is similar relative to MSCI firms. Moreover, it can be concluded that the total risk of infrastructure firms is quite close to MSCI firms with the gap being primarily driven by lower market risk.

Most of the control variables are highly significant and show the expected sign. Firm value is negatively related to corporate risk manifesting higher diversification and better developed corporate disclosure and governance mechanisms among large firms. However, it is positively related to systematic risk as larger companies tend to follow the market more closely. Sales growth is strongly positively correlated with both total and market risk indicating the uncertainty about future financials of strongly growing companies and their particular exposure to the economy. As expected, higher financial leverage entails higher market and total risk as additional debt increases the cash flow uncertainty for equity holders due the seniority of debt claims. Firms that pay dividends are less risky from a market and corporate risk point of view as dividends provide certain cash earnings and signal positive corporate prospects. The same arguments can be put forward for the negative sign of the payout ratio. However, it is never significant implying that paying dividends at all seems to matter more in terms of reducing risk than the actual dividend amount. Trading continuity which is used to proxy bid-ask-spreads[21] shows that more liquid stocks (i.e. those with higher trading continuity or lower bid-ask-spreads) have lower volatility. A higher relative trading volume entails both higher volatility and beta values as actively traded stocks follow markets more closely. The intuition that unprofitable companies are riskier both in terms of market and corporate risk is confirmed by the highly positive earnings dummy. A high book-to-market reduces volatility as those companies have less growth prospects, thus there is less uncertainty about the future. As expected, emerging market stocks have significantly higher risk than stocks from developed markets due to higher

[21]Data availability for bid-ask-spreads is more limited, therefore trading continuity is preferred as proxy. However, using bid-ask-spreads instead of trading continuity as independent variable yields the same results.

macroeconomic volatility and less sophisticated institutional frameworks.[22]

Table 5.7 shows that the results also hold when alternative regressands are used, i.e. volatility denominated in USD, world betas, international betas, and local asset betas. The regression results are also robust across time, i.e. when analyzing only one cross-section of data instead of the three cross-sections as depicted in Table 5.8.

In summary, infrastructure can be characterized as an 'average volatility, low beta' business. The total corporate risk of infrastructure firms and for most of its subsectors is comparable to MSCI stocks, contradicting H1.1. However, systematic risk of listed infrastructure is lower than for other equities, affirming H1.2. Market betas are particularly low for transport and utility assets, whereas telecommunication firms are associated with betas similar to average stocks. There is a sizable variation of risk across all risk metrics and between infrastructure subsectors bringing forth the cognition that there is no such thing as a 'standard infrastructure asset' with universally low investment risk.

[22]The unexpected result that emerging market stocks have higher systematic risk can be explained by the fact that these stocks often make up a considerable part of their home country indices and are therefore more correlated to these indices.

Table 5.6: Regression results: Corporate, systematic, and idiosyncratic risk

	Local Volatility	**Local Volatility**	**Local Beta**	**Local Beta**	**Idiosyn. Volatility**	**Idiosyn. Volatility**
ln_FirmValue	-0.021***	-0.024***	0.054***	0.046***	-0.031***	-0.033***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SalesGrowth	0.069***	0.062**	0.292***	0.271***	0.048**	0.043*
	(0.005)	(0.011)	(0.000)	(0.000)	(0.043)	(0.070)
ln_Leverage	0.008***	0.009***	0.013***	0.016***	0.006***	0.007***
	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)
DivPayout_D	-0.151***	-0.140***	-0.285***	-0.251***	-0.142***	-0.134***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DivPayout	-0.007	-0.006	-0.008	-0.006	-0.005	-0.005
	(0.254)	(0.260)	(0.591)	(0.635)	(0.244)	(0.250)
TradCont	-0.210***	-0.199***	0.065	0.111*	-0.208***	-0.199***
	(0.000)	(0.000)	(0.323)	(0.093)	(0.000)	(0.000)
ln_RelTradVol	0.019***	0.019***	0.057***	0.056***	0.014***	0.014***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EP_D	0.104***	0.096***	0.221***	0.197***	0.091***	0.084***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EarningsPrice	-0.018	-0.011	0.034	0.062	-0.028	-0.023
	(0.398)	(0.589)	(0.437)	(0.180)	(0.289)	(0.374)
BookMarket	-0.004**	-0.003	0.000	0.004	-0.005***	-0.004**
	(0.040)	(0.117)	(0.976)	(0.398)	(0.008)	(0.016)
Emerging_D	0.085***	0.082***	0.075***	0.067***	0.031***	0.029***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Infra_D	-0.029***		-0.252***		-0.006	
	(0.000)		(0.000)		(0.261)	
Telecom_D		0.047***		-0.017		0.055***
		(0.000)		(0.546)		(0.000)
Transport_D		-0.058***		-0.255***		-0.036***
		(0.000)		(0.000)		(0.000)
Utilities_D		-0.063***		-0.381***		-0.032***
		(0.000)		(0.000)		(0.000)
Constant	0.920***	0.925***	0.757***	0.758***	0.916***	0.922***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N	7,423	7,423	7,423	7,423	7,423	7,423
Adj. R-square	0.302	0.316	0.215	0.235	0.327	0.339

Note: The table reports OLS coefficient estimates and p-values based on robust standard errors (in parentheses) for different regression models and independent variables. ***, ** and * indicate statistical significance at the 1%, the 5%, and the 10% levels (two-tailed), respectively.
Source: Rothballer and Kaserer (2012b)

Table 5.7: Robustness test: Regression results for alternative regressands

	Local Volatility	**USD Volatility**	**Local Beta**	**World Beta**	**International Beta**	**Local Asset Beta**
ln_FirmValue	-0.021***	-0.019***	0.054***	0.065***	0.074***	0.024***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SalesGrowth	0.069***	0.069***	0.292***	0.301***	0.302***	0.200***
	(0.005)	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)
ln_Leverage	0.008***	0.009***	0.013***	0.020***	0.011**	-0.093***
	(0.000)	(0.000)	(0.003)	(0.000)	(0.036)	(0.000)
DivPayout_D	-0.151***	-0.147***	-0.285***	-0.316***	-0.346***	-0.184***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DivPayout	-0.007	-0.007	-0.008	-0.011	-0.009	-0.005
	(0.254)	(0.244)	(0.591)	(0.525)	(0.599)	(0.604)
TradCont	-0.210***	-0.453***	0.065	-0.181	0.142	0.118**
	(0.000)	(0.000)	(0.323)	(0.258)	(0.364)	(0.024)
ln_RelTradVol	0.019***	0.017***	0.057***	0.052***	0.057***	0.044***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EP_D	0.104***	0.108***	0.221***	0.243***	0.212***	0.119***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EarningsPrice	-0.018	0.008	0.034	0.191	0.134	-0.008
	(0.398)	(0.557)	(0.437)	(0.156)	(0.329)	(0.740)
BookMarket	-0.004**	-0.005**	0.000	0.009	0.018**	-0.005
	(0.040)	(0.037)	(0.976)	(0.296)	(0.046)	(0.244)
Emerging_D	0.085***	0.114***	0.075***	0.304***	0.209***	0.019*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.054)
Infra_D	-0.029***	-0.029***	-0.252***	-0.236***	-0.198***	-0.192***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.920***	1.140***	0.757***	0.933***	0.502***	0.491***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)
N	7,423	7,390	7,423	7,390	7,335	7,423
Adj. R-square	0.302	0.314	0.215	0.174	0.153	0.291

Note: The table reports OLS coefficient estimates and p-values based on robust standard errors (in parentheses) for different regression models and independent variables. ***, ** and * indicate statistical significance at the 1%, the 5%, and the 10% levels (two-tailed), respectively.
Source: Rothballer and Kaserer (2011)

Table 5.8: Robustness test: Regression results for subperiods

	Local Volatility 1995-1999	**Local Volatility 2000-2004**	**Local Volatility 2005-2009**	**Local Beta 1995-1999**	**Local Beta 2000-2004**	**Local Beta 2005-2009**
ln_FirmValue	-0.023***	-0.022***	-0.027***	0.046***	0.056***	0.009
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.199)
SalesGrowth	-0.015	0.074	0.149***	0.137**	0.420***	0.252***
	(0.764)	(0.112)	(0.000)	(0.045)	(0.000)	(0.000)
ln_Leverage	0.006**	0.004	0.015***	0.005	-0.013	0.055***
	(0.011)	(0.191)	(0.000)	(0.382)	(0.142)	(0.000)
DivPayout_D	-0.090***	-0.211***	-0.108***	-0.220***	-0.355***	-0.175***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DivPayout	-0.079***	-0.002	-0.012	-0.170***	0.001	-0.010
	(0.000)	(0.558)	(0.267)	(0.000)	(0.921)	(0.666)
TradCont	-0.308***	-0.334**	-0.060	0.189	0.026	0.096
	(0.000)	(0.010)	(0.180)	(0.152)	(0.833)	(0.307)
ln_RelTradVol	0.016***	0.024***	0.017***	0.033***	0.059***	0.079***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EP_D	0.080***	0.127***	0.067***	0.109***	0.408***	0.091***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
EarningsPrice	-0.318*	-0.128	-0.013	-0.604	-0.258	0.053
	(0.075)	(0.380)	(0.121)	(0.104)	(0.461)	(0.423)
BookMarket	-0.003	0.001	-0.009**	-0.004	0.012	0.000
	(0.188)	(0.876)	(0.016)	(0.418)	(0.336)	(0.969)
Emerging_D	0.170***	0.034***	0.065***	0.162***	0.048*	0.007
	(0.000)	(0.002)	(0.000)	(0.000)	(0.054)	(0.717)
Infra_D	-0.032**	0.004	-0.044***	-0.248***	-0.147***	-0.384***
	(0.023)	(0.731)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.996***	1.084***	0.809***	0.626***	0.644***	1.324***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N	1,917	2,516	2,990	1,917	2,516	2,990
Adj. R-square	0.408	0.359	0.279	0.265	0.252	0.250

Note: The table reports OLS coefficient estimates and p-values based on robust standard errors (in parentheses) for different regression models and independent variables. ***, ** and * indicate statistical significance at the 1%, the 5%, and the 10% levels (two-tailed), respectively.
Source: Rothballer and Kaserer (2011)

5.4 Discussion

5.4.1 Reasons for idiosyncratic risk

The finding that infrastructure is a 'average volatility, low beta' business implies that infrastructure has a similar level and an even higher share of idiosyncratic risk in comparison to other industries. Some additional sources of idiosyncratic risk seem to be compensating the light competition, strong pricing power, and little operational and R&D risks. Possible explanations during the investment phase include the high decision uncertainty, the lack of project diversification, and construction risks. Moreover, during asset operation infrastructure firms have to cope with operating leverage, external shocks, regulatory changes, and little product and geographic diversification.

The investment in new infrastructure assets involves complex decisions under high uncertainty as they are based on long-term demand forecasts matching the asset lives of multiple decades. Under these circumstances, executives often fall victim to the planning fallacy and principal-agent issues are particulary pronounced (Flyvbjerg et al. (2009)). Various studies show the lack of predictive accuracy in traffic forecasts and the considerable optimism bias inherent to these projections. Bain (2009) finds that the traffic forecasts across 100 toll road projects are characterized by large errors as actual traffic ranges from 14% to 151% with an average of 77% relative to the forecast. Muller (1996) reports that only one out of 14 evaluated toll road projects exceeded its original revenue forecast, and Baeza and Vassallo (2010) find that traffic for 15 toll roads in Spain is on average 50% below the predicted level. These forecast errors have even lead to bankruptcies, such as the Dulles Greenway in Virginia which defaulted in 1996 when toll revenues were only 20% of its first year forecast. Similar evidence is available for other sectors. For example, the 2008 traffic at U.S. airports turned out to be 13.3% lower on average than the forecasts from 2004, as unpredictable circumstances such as airline mergers, hub closures, and low-cost-carrier entry affect the local passenger volumes (de Neufville (2011)). In the extreme case of Cincinnati the actual passenger number was only half the forecast – despite the short forecasting period of just four years. Another prominent example for traffic overestimation includes the bankruptcy of thirteen U.S. railroads which went into administration between 1893 and 1898 due to their oversized networks (Daggett (1908)).[23] The investment decision making risk is exacerbated by the fact that product testing is not possible and most investments need to be committed in one 'batch', i.e. capacity additions are indivisible often causing initially large overcapacities. The large-scale nature of infrastructure assets implies that infrastructure firms decide on few but relatively large investments, e.g. a new terminal building or a power plant. The low project diversification implies an even stronger exposure to potential flaws in the decision making process and a high dependence on single projects.

Besides the investment decision process, the construction phase also involves significant idiosyncratic cost, timing, and quality risk. The management and execution of large, specific, and non-recurring construction projects is complex and prone to failures. An analysis of Flyvbjerg et al. (2003b) showcases the significant average cost escalations above plan for rail (45%), tunnels and bridges (34%), and roads (20%). Cost overruns are a consistent global phenomenon and have not been reduced over time despite learnings from previous failures and technological innovation. The risks tend to be higher for larger projects, for longer implementation phases, and for greenfield projects (Flyvbjerg et al. (2004)). Prominent examples for construction cost overruns and delays include the Channel tunnel, the Great Belt bridge, and the Oresund link (Flyvbjerg et al. (2003a)).

Once an infrastructure asset has been erected, its usage is very specific and bounded to a particular location. Investments are therefore sunk entailing high fixed costs in the form of depreciation charges and maintenance costs. This causes

[23] This forecast uncertainty is due to the complex modeling process – mostly using discrete choice analysis – which requires extensive, but uncertain input for demographic, socioeconomic, macroeconomic, transportation network, and land-use variables. Assumptions about the travel characteristics (demand, cost, speed), the value of time (which is heterogeneous across user groups, trip purposes, travel time, vehicle occupancy, congestion), the willingness to pay, and the toll fare structure are difficult to make, particularly when stated preference data are used.

high operating leverage and a strong exposure to sales declines and external shocks. While operating leverage is usually considered to impact systematic risk (Lev (1974)), it can also be unsystematic if the negative event of declining sales for a particular company is uncorrelated to the macroeconomic environment or other companies' sales development. In any adverse external event, be it a demand shock or technological progress, infrastructure firms have little possibility to adapt as their assets are specific, location-bounded, and of long durations. While demand shocks can be caused by changing geographic population or economic patterns, technology shocks occur when disruptive innovations become available. Examples include the development of LNG gas transport on tankers which rendered some pipelines redundant and the introduction of wireless telecommunication creating strong competition for established fixed-line networks. Similarly, Gander international airport, which was the main hub for transatlantic flights in the pre-jet-aircraft age and the busiest airport in the world at the time, invested in new terminals and runways in the 50s, but never recovered this investment since the introduction of long-range jets rendered the airport obsolete as planes were able to fly from Europe to the U.S. non-stop. Currently, the emergence of regenerative energy generation, smart grid technology, and high-speed rail may pose a similar threat to established infrastructure systems. Though rare, natural disasters and major technical breakdowns provide an additional source of unsystematic risk exposure for infrastructure firms due to their geographically concentrated physical assets.

In addition, many infrastructure companies are regulated by governments or regulatory authorities due to their quasi-monopolistic market position. By prescribing prices, investments, and service quality, regulation has a severe impact on profitability. If governments do not stay committed to the ex-ante regulated prices, regulatory mechanisms, or the policy framework that protect the sunk investments, this can potentially have a significant effect on the financial situation. Regulatory risk is partly unsystematic as regulatory decisions usually only affect certain players in an industry and are unrelated to the general economy. For example, the U.K. water and electricity regulators have tightened the efficiency targets in their price cap formulas after 1994 redistributing efficiency gains between investors and consumers and imposing greater risks of operational improvements onto operators (Robinson and Taylor (1998), Parker (1999), Parker (2003), Buckland and Fraser (2000)). Changes of the regulatory regime itself, such as the change from cost-plus to incentive regulation for the German electricity and gas transmission networks in 2009, can have a similar adverse impact, as price cap regimes are associated with higher levels of shareholder risk (compare sections 3.2.1.2 and 3.2.2.2). Another example of regulatory risk includes the recent retrospective adjustments of the solar feed-in tariffs in Spain (Deloitte (2011)). The time inconsistency between political and regulatory cycles and infrastructure investment durations, also furthers this exposure to idiosyncratic risk. This is of particular concern in emerging markets where the political system and its institutions are often fragile. Moreover, the deregulation and liberalization of infrastructure industries (e.g. mandatory unbundling or third-party network access rules) have exposed many firms to increasing competitive pressure and hence idiosyncratic risks. Though outright expropriations became rare, creeping expropriation through detrimental regulation is an increasing idiosyncratic risk for infrastructure investors, which is typically not covered by political risk insurance (Sawant (2010b)).

Moreover, infrastructure companies are usually little diversified across products and geographies. Vertical product diversification is impeded by structural separation requirements in many industries, e.g. for railways and utilities. Though horizontal product diversification is observable in practice (e.g. retail business for airports, media business for telecommunication), its scale is limited. The little geographic diversification originates in the fact that many infrastructure companies are formerly publicly-owned, hence serving just their home city, region, or country. But even after privatization, geographic expansion of infrastructure companies is hindered by little economies of scale across geographies, the requirement to localize "production" (as "exports" are not feasible), and foreign ownership caps for assets deemed critical for society and state security. For instance, most airport companies in the sample only operate at one location, e.g. Copenhagen, Beijing, Bangkok, Auckland, and Vienna.

All factors discussed above are hypothesized to contribute to the unexpectedly high level of idiosyncratic risk of infrastructure. Therefore, I test whether some of these factors can indeed explain a part of the idiosyncratic risk empirically. For this purpose, four additional independent variables are introduced in the original regression model: $CapexVola_{i,t}$ to proxy for construction risks, $EbitMarginVola_{i,t}$ for operating leverage, $EmergingInfra\_D_i$[24] for regulatory risk (and construction risk)[25], and the number of SIC codes $SICs_i$ for product diversification.[26] As the availability of these additional variables is limited, the sample size is further reduced. I only analyze the last cross-section of data (2005-2009) as historical SIC codes are not available and both capital expenditure volatility and EBIT-margin volatility require more than five annual observations to be meaningfully calculated.

The results in Table 5.9 indicate that the additional variables are capable to explain a part of the idiosyncratic risk of infrastructure stocks. All additional proxies show the expected signs (and are mostly significant) as firms with higher capex volatility, higher EBIT margin volatility, emerging market infrastructure, and less SIC codes have higher idiosyncratic risk. After inserting the additional variables, the infrastructure dummy changes from -1% to -4% and becomes substantially more significant. None of the three sector dummies for telecom, transport, and utilities is significant prior to inserting the additional proxies, but they all turn negatively significant in the extended model.[27] In summary, this test supports the above stated interpretation that construction risks, operating leverage, regulatory risks, and the lack of product diversification are among the causes for the high idiosyncratic risk found for infrastructure firms. Including the additional proxies also increases the

[24] $EmergingInfra\_D_i$ is the interaction term of $Emerging\_D_i$ and $Infrastructure_i$.

[25] Regulatory risk is deemed to be higher in emerging markets where institutional frameworks tend to be less stable. Also, emerging market infrastructure has a higher share of greenfield construction projects.

[26] Refer to section 4.4 for the definition of these variables.

[27] An additional analysis shows that some of the excessive share of idiosyncratic risk can be explained by adding the additional variables – though the share of idiosyncratic risk is still significantly higher for infrastructure stocks when controlling for the additional factors.

explanatory power of the model, though the increase is marginal as the proxies are relatively 'fuzzy' and not able to fully capture the underlying economic determinants.[28]

5.4.2 Policy and investor implications

The empirical finding of high exposure to idiosyncratic risks stresses the importance that infrastructure investors are well diversified, otherwise they would require significant cost of capital premiums. Previous research found that in countries with low levels of risk diversification opportunities, i.e. countries with less developed financial markets such as continental Europe as opposed to the Anglo-Saxon countries, sectors characterized by high idiosyncratic volatility perform worse in terms of productivity, investment, and business creation (Michelacci and Schivardi (2008)). Hence, if idiosyncratic risks of infrastructure investments are not diversifiable, this possibly implies underinvestment in infrastructure causing an inherent tendency of sector underperformance and hindering growth. This fosters the crucial role of financial intermediaries in financing infrastructure as they redistribute risk among multiple investors, besides their role in transforming lot sizes. This is compounded by the fact that for many PPP and privatization tenders the bidding consortia are restricted to a few sponsors, thus limiting the risk diversification scope. For instance, the Build-Operate-Transfer (BOT) project for a high-speed rail link between Taipei and its international airport was abandoned by the two contractors citing financial problems due to the large project. As a result, infrastructure funds have proliferated over the past years taking an increasing share of the infrastructure finance market (Hall (2006), Helm and Tindall (2009)).

The high share of unsystematic risks also explains the extensive involvement of governments in infrastructure finance. As large countries are per se well diversified through the taxation system and the diversity of the public sector, they are able to bear the large idiosyncratic risks of infrastructure investments (Quiggin

[28]The other factors contributing to the idiosyncratic risk exposure, e.g. forecast uncertainty, cannot be meaningfully measured empirically with the available data.

Table 5.9: Regression results for extended model: Idiosyncratic risk

	Idiosyn. Volatility	**Idiosyn. Volatility**	**Idiosyn. Volatility**	**Idiosyn. Volatility**
ln_FirmValue	-0.027***	-0.025***	-0.027***	-0.025***
	(0.000)	(0.000)	(0.000)	(0.000)
SalesGrowth	0.104***	0.075**	0.104***	0.075**
	(0.001)	(0.017)	(0.001)	(0.016)
ln_Leverage	0.009***	0.010***	0.009***	0.010***
	(0.000)	(0.000)	(0.000)	(0.000)
DivPayout_D	-0.073***	-0.058***	-0.073***	-0.058***
	(0.000)	(0.000)	(0.000)	(0.000)
DivPayout	-0.006	-0.006	-0.006	-0.006
	(0.183)	(0.148)	(0.183)	(0.149)
TradCont	-0.026	-0.019	-0.025	-0.019
	(0.466)	(0.596)	(0.480)	(0.600)
ln_RelTradVol	0.014***	0.014***	0.014***	0.014***
	(0.000)	(0.000)	(0.000)	(0.000)
EP_D	0.060***	0.052***	0.060***	0.053***
	(0.000)	(0.000)	(0.000)	(0.000)
EarningsPrice	-0.103	-0.101	-0.102	-0.101
	(0.181)	(0.208)	(0.182)	(0.210)
BookMarket	-0.006***	-0.005**	-0.006***	-0.005**
	(0.006)	(0.018)	(0.007)	(0.020)
Emerging_D	0.042***	0.019***	0.042***	0.019***
	(0.000)	(0.001)	(0.000)	(0.001)
Infra_D	-0.010*	-0.040***		
	(0.098)	(0.000)		
Telecom_D			-0.009	-0.044***
			(0.405)	(0.001)
Transport_D			-0.005	-0.036**
			(0.704)	(0.011)
Utilities_D			-0.011	-0.040***
			(0.144)	(0.000)
CapexVola		0.023*		0.023*
		(0.064)		(0.068)
EbitMarginVola		0.038***		0.038***
		(0.005)		(0.005)
EmergingInfra_D		0.069***		0.069***
		(0.000)		(0.000)
SICs		-0.002		-0.002
		(0.106)		(0.102)
Constant	0.635***	0.614***	0.633***	0.612***
	(0.000)	(0.000)	(0.000)	(0.000)
N	2,234	2,234	2,234	2,234
Adj. R-square	0.310	0.335	0.310	0.335

Note: The table reports OLS coefficient estimates and p-values based on robust standard errors (in parentheses) for different regression models and independent variables. ***, ** and * indicate statistical significance at the 1%, the 5%, and the 10% levels (two-tailed), respectively.
Source: Rothballer and Kaserer (2012b)

(1996)). In contrast, many smaller countries might be insufficiently diversified to finance large-scale infrastructures and thus require the assistance of private investors or international financial institutions (Chowdhury et al. (2009), Kennedy and Orr (2007)). But also private infrastructure finance is often not feasible without government support. In many PPP arrangements governments commit to contract terms mitigating certain idiosyncratic risks for private investors. For example, for tunnel construction projects governments often guarantee drilling risks as private financiers are not willing to cover this idiosyncratic risk (Checherita and Gifford (2008)). Similarly, for some highway projects governments agree to non-competition clauses for other transport modes such as mass transit. For these reasons, the risk sharing between public and private partners deserves particular attention during the legal set up of PPP projects as it is one of the most critical success factors (Kwak et al. (2009), Välilä (2005)). For example, these long-term PPP contracts need to be structured sufficiently flexible to address future idiosyncratic events appropriately (Dong and Chiara (2010)).

The finding that the risk profiles of infrastructure sectors are highly diverse also has important implications for investors. As each infrastructure asset is unique in its competitive situation and regulatory framework substantial due diligence efforts are required. For example, the \$3.6 billion financing of the Baku-Tbilisi-Ceyhan pipeline was negotiated over ten years and required 208 documents and 17,000 signatures from 78 parties (Chen (2004)). In addition, specialist analysis and investment selection capabilities as well as a profound understanding of the sectors, assets, and regulatory frameworks are required to properly evaluate the peculiar asset, assess its financial viability, and to successfully execute an infrastructure investment strategy (Vanguard (2009)). For many investors that lack these skills, an in-sourcing of infrastructure investing seems not feasible (Clark et al. (2011)). In fact, the evolving infrastructure fund market with increasing specialization on project stages, regions or sectors, offers adequate products to address these shortcomings and mitigate the above risks effectively (Preqin (2008)). Also the risk management capabilities of infrastructure operators, i.e. the ways how they identify, assess, mitigate, and monitor construction, volume or regulatory risk is of paramount importance to success. Advanced risk simulation and valuation tools that holistically capture all sources of risk and their interactions provide a considerable value contribution. But the large idiosyncratic risks and high volatility also makes real options on infrastructure assets highly valuable. Hence, the application of real options may prove worthwhile due to the high uncertainty of long-term forecasts and the long investment horizons (Geltner and de Neufville (2012), de Neufville et al. (2006)). For example, the original design of the bridge across the Tagus included the flexibility to accommodate railroad traffic at a later stage to provide an efficient connection to the existing urban rail system, which was actually implemented many years after the initial construction (Gesner and Jardim (1998)).

5.4.3 Limitations

The analyzed sample does not cover the whole spectrum of the infrastructure asset class. While it includes all forms of regulation (unregulated, incentive, and cost-plus), maturity (brownfield and greenfield), and geography (developed and emerging countries), it is restricted in terms of sectors (only economic infrastructure, no social infrastructure such as prisons, hospitals, schools), entity type (only listed corporations, no unlisted corporations, no funds, no single assets[29]) and public sector risk sharing (mostly privatized assets, no PPPs). Hence, a generalization of the results to these other infrastructure asset types is only possible to a limited extent. Particularly, the investment characteristics of social infrastructure and of many transport PPP arrangements that limit the risk transfer to the private sector, e.g. by excluding traffic risks, are supposedly different. Those assets rather resemble long-term real estate lease contracts with solvent counterparties. Further studies are required to specifically analyze the risk characteristics of PPPs and social infrastructure assets and to compare listed to unlisted infrastructure. Moreover, the evidence is based on firms, not on assets. Some factors in the firm structure such

[29] Firms can be understood as a bundle of assets, each of them being in a specific development stage, i.e. firms are a mix of greenfield and brownfield projects.

as principal-agent issues or the employed financing mechanisms, may distort the fundamental cash flow perspective of infrastructure assets.

While the overall sample size is satisfactory, the sample size for some subsectors is relatively low. For example, the total number of satellite, airport, highway, port, and pipeline companies is less than 50, respectively. Furthermore, some of the subsector results are driven by certain regions where privatizations have yet occurred. For example, there is no North American airport or highway in the infrastructure sample. Similarly, emerging market representation is poor for transportation subsectors, but also for water and gas utilities. Future studies could benefit from larger cross-sections due to the ongoing privatization trend, particularly in the transportation sector.

As infrastructure is still a young equity segment, the analysis relies on a time series of 12 years on average across all sample entities. Predictions based on these results should therefore done with caution as long-term conclusions are difficult to derive from such a short analysis timeframe, especially for long-lived assets such as infrastructure. In addition, the asset class itself will evolve further in the future driven by increasing infrastructure asset supply and demand as well as regulatory changes.

5.5 Synopsis

Even though infrastructure investments have gained increasing investor attention, the empirical evidence on their actual risk characteristics is still limited. To fill this gap, I analyze the risk properties of a unique cross-sectional sample of more than 1,400 publicly listed infrastructure firms worldwide across all infrastructure sectors. I find that infrastructure stocks on average exhibit significantly lower market risk than MSCI World equities, showcasing their portfolio diversification benefits. Yet, as there are large variations within the infrastructure asset class, the low risk hypothesis cannot be maintained for all sectors. In contrast to the widespread belief that total corporate risk is lower for infrastructure firms, I show that infrastructure firms across all sectors exhibits a similar volatility as non-infrastructure firms. Hence, infrastructure is characterized by significant exposure to idiosyncratic risks despite lower competition and little operational risks in infrastructure industries. This peculiar risk profile can be partly explained by construction risks, high operating leverage, the exposure to regulatory changes, and the lack of product diversification. Moreover, I observe a sizeable variation within the infrastructure asset class for both total and market risk, with utilities being the least risky, followed by transportation and telecommunication. This brings forth the cognition that there is no such thing as a "standard infrastructure asset" with universally low investment risk. The actual risk characteristics rather depend on a large variety of factors such as the sector, the regulatory regime, asset maturity, and geography.

With regard to public policy, the results point out that governmental financial support schemes (e.g. guarantees) may be warranted for socially beneficial infrastructure projects if idiosyncratic risks along with insufficient diversification impede investments. For investors these findings highlight the need for diversified infrastructure portfolios, advanced risk management capabilities (e.g. real options), and efficient risk sharing mechanisms between the private and public sectors. Moreover, the diverse risk profiles of infrastructure sectors require investors to develop an in-depth understanding of the sectors, the regulatory frameworks, the market positions, and the competitive environment in order to invest in the right assets that provide the desired risk properties.

Chapter 6

The Impact of Infrastructure Regulation on Risk

The aim of this chapter is to empirically analyze the relationship between price regulation and systematic risk. A brief background on the changes in the regulatory environment over the past decades and a summary of the previous literature motivates the hypotheses. After presenting the methodological approach, the empirical results for the impact of the existence of price regulation, the regulatory regime, and regulatory independence are described. Lastly, the findings are discussed and implications for investment management and public policy are derived. This chapter is based on Rothballer and Kaserer (2012a).

6.1 Motivation

Over the past decades, deregulation and privatization have transformed infrastructure industries around the world. Competition was enhanced through horizontal and vertical unbundling and the establishment of non-discriminatory third party network access rules. As former natural monopolies were shifting towards a more competitive environment, tariff regulation was abandoned or alleviated where technological advances changed the minimum efficient scale (e.g. telecom) or where structural reforms enforced competition (e.g. electricity generation). At the same time, the ongoing privatization trend subjected an increasing number of formerly state-owned infrastructure assets (e.g. transportation) to price regulation.

Besides the alterations in the scope of price regulation, the universe of regulatory regimes became more diverse. The shortcomings of the historically prevailing rate-of-return regulation, such as overinvestment (Averch and Johnson (1962)) and poor efficiency incentives have led to the development of alternatives, most notably incentive regulation which was first introduced in the context of the privatization of British Telecom (Littlechild (1983)). In the subsequent decades, incentive regulation proliferated and is today applied in up to 50% of the OECD countries across most regulated infrastructure sectors (Égert (2009)). Though its virtues of increased productive efficiency are widely documented, its potential drawback of higher cost of capital is not yet thoroughly analyzed empirically.[1] Along with deregulation and changes in the design of price regulation, many countries institutionalized independent "at arm's length" regulators to perpetuate regulatory policies, reduce political interferences, and provide credible signals to firms for sunk cost recovery.

This continuously evolving and increasingly diverse regulatory landscape gives reason to an empirical review of the impact of price regulation, the regulatory regime, and regulatory independence on the market risk of infrastructure firms. The effects of regulation are relevant for all stakeholders concerned with essential infrastructure services. Consumers and regulators worry about the impact regulation eventually has on capital costs and output prices. Similarly, producers are concerned about the level of risk they have to bear and the associated returns they are able to generate in order to satisfy their shareholders' demands. A recent survey of Ernst&Young (2010) reveals that utility and telecom companies perceive regula-

[1] Further disadvantages of incentive regimes, such as potential quality deteriorations and the lack of investment incentives, motivated governments to experiment with hybrid regimes aiming at both allocative and productive efficiency and balancing investment, quality, and efficiency incentives.

tory and compliance risk as the greatest threat to their business, being more critical than financing, talent management, competition, and the macroeconomy. The level of risk and the cost of capital are also of paramount importance in attracting new investors to address the global infrastructure funding gap (OECD (2007)).

Previous empirical studies show that Peltzman (1976)'s buffering hypothesis that price regulation reduces market risk is mostly confirmed (Norton (1985), Chen and Sanger (1985), Fraser and Kannan (1990), Binder and Norton (1999), Nwaeze (2000), Buckland and Fraser (2001), Sidak and Ingraham (2003)), except for time periods with rising factor prices and in emerging markets (Davidson et al. (1997), Barcelos and da Silveira Bueno (2010)). The datasets used in these studies only include firms under the highly regulated market environments of the 1970s and 1980s, and are limited to certain countries (U.S., U.K.) and sectors (electricity, telecom). I complement the existing empirical studies on the link between price regulation and market risk, by extending the evidence for the Peltzman hypothesis to a cross-country, cross-sector dataset of 764 telecom, utility, and transport infrastructure firms, that operate in a more liberalized market environment:[2]

H2.1: Price regulation reduces market risk

I also contribute to the literature by analyzing the influence of the regulatory regime on market risk which has so far received little attention and where previous empirical results are ambiguous. While some studies (Alexander et al. (1996), Alexander et al. (2000), Grout and Zalewska (2006)) confirm the regulatory theory that high-powered incentive regimes imply higher systematic risk, later panel regressions that explicitly control for other risk factors (Gaggero (2007), Gaggero (2012)) contradict this hypothesis. Therefore, I reinvestigate the following hypothesis with a large sample and an econometrically sound methodology controlling for a variety of confounding factors including other regulatory variables:

H2.2: Incentive regulation increases market risk relative to cost-based regulation

Regulatory theory suggests that independent regulators solve the commitment

[2] The existing theoretical and empirical literature relating to this and the following hypotheses is presented in detail in section 3.2.

problem that arises because of the time-inconsistency between political cycles and the duration of infrastructure investments (Kydland and Prescott (1977)). Independent regulators reduce political interference and opportunism and thus signal sunk cost recovery and adequate returns. But to the best of my knowledge, no study has yet empirically investigated the effect of regulatory independence on systematic risk, though other empirical studies document the potential benefits of regulatory independence for other regulatory outcomes such as investments and efficiency. To fill this gap, I analyze the following hypothesis:

H2.3: Regulatory independence reduces market risk

6.2 Methodology

6.2.1 Regulatory data

Data on the existence of price regulation, the employed regulatory regime and the independence of the sector regulator are obtained from a 2007 OECD survey of infrastructure industries in 24 member countries[3] and are complemented by manual research for 22 further countries as described in section 4.5.3.

For firms that are subject to (partial)[4] price regulation, the dummy $PriceRegulation\_D_i$ is set equal to 1 (0.5), and 0 otherwise.[5] The dummy $IncentiveRegulation\_D_i$ assumes 1 when incentive regulation (rate freeze, price cap, revenue cap, rate-case moratoria, yardstick) is applied, and 0 if prices are unregulated or set according to cost-based regulation (e.g. rate-of-return (RoR)).[6] As this variable is contingent on $PriceRegulation\_D_i$, it captures the incremental ef-

[3]The same data are used by Égert (2009). The OECD dataset covers about 60% of the firms in the sample. The regulatory data are matched to each firm based on its sector and country of main operations. For firms active in multiple sectors averaged regulatory data are used as described in Table 4.18.

[4]Partial price regulation means that not all of the firm's output prices are regulated.

[5]The used dataset does not contain information on whether a price regulation is binding or whether the charged prices are actually below the regulated prices as it is the case for some telecom markets.

[6]A more refined classification of regimes is not feasible based on the OECD data. Notwithstanding, 0.5 is used for hybrid regimes (e.g. sliding scale, earnings sharing, price cap with cost pass-through) for manually researched data.

fect that high-powered regulation has on market risk. The dummy $Independence\_D_i$ describes whether a de jure independent authority regulates the sector.[7] A dummy value of 0 refers to a government regulator (decision rights entitled to the executive, parliament, or any government agency), 1 to an independent regulator (powers assigned to an independent authority or competition authority), and 0.5 to a semi-independent regulator (shared powers between independent and dependent regulators). I also include the interaction term of $IncentiveRegulation\_D_i$ and $Independence\_D_i$, i.e. $IndependentIncentive\_D_i$, after centering both original variables around the mean to reduce collinearity (Smith and Sasaki (1979)).[8]

The country-specific quality of the institutional endowment is measured by the average of the six Worldwide Governance Indicators (WGI) (Kaufmann et al. (1999)) captured in the variable $CountryGovernance_i$ as described in section 4.5.1. Higher values correspond to better governance outcomes (Kaufmann et al. (2009)). The variable $MarketCompetition_i$ measures the legal entry barriers, the market structure, and the vertical integration of infrastructure sectors across countries (OECD (2007)) as described in section 4.5.2. It ranges between 0 and 6, where 0 refers to an accessible and 6 to a closed market.[9]

6.2.2 Regression model

Since the regulatory dataset does not have a time dimension, a panel regression is not feasible. However, the benefits of panel data may be small since regulatory changes occur slowly over time. In Gaggero (2012)'s panel over 10 years, only 18

[7] Note, that the de-facto regulatory practice may deviate from the de-iure set-up. However, this possibility cannot be captured in this variable.

[8] Mean-centering implies that for each observation the variable's mean is substracted from the original value yielding a transformed variable with mean zero, but with the same standard deviation. This procedure reduces the correlations between the interaction term and the two basic variables.

[9] The dataset covers the electricity, gas, rail, fixed-line and wireless sectors, and hence the majority of the sample firms. For subsectors where data are missing (water, airport, port, highway, pipeline, and multi utility) the corresponding data of subsectors in the same sector are applied (e.g. pipeline is proxied by gas utilities). Similarly, for missing non-OECD countries averaged data from their respective regional peers are applied.

out of 170 firms (approximately 10%) experienced a switch of the regulatory regime. I estimate the following cross-sectional regression using ordinary least squares:

$$\beta_i = \alpha + \gamma_1 \mathbf{C}_i + \gamma_2 \mathbf{X}_i + \delta_1 \mathbf{S}_i + \delta_2 \mathbf{R}_i + \epsilon_i \tag{6.1}$$

where β_i is the measure for systematic risk, α is the constant term, $\mathbf{C}_i$ is a vector of firm-level controls, $\mathbf{X}_i$ is a vector of regulatory variables, $\mathbf{S}_i$ is a vector of sector dummies[10], and $\mathbf{R}_i$ is a vector of region dummies[11]. As dependent variable for systematic risk, the local equity betas β_i and asset (unlevered) betas β_i^u are used as previously derived in equation 5.11 and 5.16 in section 5.2.1. The betas are based on return data from the five year period from 2005 until 2009 to match the regulation data, which are from around 2007. Firms with negative beta estimates are dropped from the sample. The firm-level variables of Table 6.1 are used to control for other risk factors besides regulation in the regression. The same proxies for size, growth, leverage, dividends, liquidity, profitability and book-to-market as in section 5.2.3 are applied. Analogous to the return data, the accounting and financial market data are averaged for the time period from 2005 till 2009. Besides the set of control variables, the dummies for infrastructure sectors and geographic regions account for the sample's heterogeneity and potential omitted variables.[12]

The above equation is estimated with clustered standard errors based on Liang and Zeger (1986) to address heteroscedasticity and intra-group correlation of error terms. Clustering on the country-sector level would take care of the intra-cluster correlation but inter-cluster correlation would remain since correlation within countries (a given country may apply similar regulation across sectors) and within sectors (sectoral reforms spill over to other countries; international organizations promote

[10]Sector dummies: Wireless, Fixed-line, Airports, Pipelines, Ports, Highways, Railroads, Water, Electricity - integrated, Electricity - generation, Electricity - transmission, Electricity - distribution, Gas distribution, Multi utility.

[11]Region dummies: North America, Latin America, Western Europe, Eastern Europe, Africa & Middle East, Asia-Pacific.

[12]A systematic bias due to country effects such as political stability, the quality of governance, and the rule of law, can be precluded as *CountryGovernance* captures these risk factors. However, a robustness test using a country fixed effects model is provided.

Table 6.1: Definition of firm-level control variables

Regressor	Definition
$ln\_FirmValue_i$	Natural logarithm of the market value of equity plus the book value of debt
$SalesGrowth_i$	Continuously compounded annual growth rate of sales
$ln\_Leverage_i$	Natural logarithm of the book value of total debt divided by the market value of equity
$DivPayout\_D_i$	Dummy that is 1 if the firm paid dividends in any of the 5 years, otherwise 0
$DivPayout_i$	Ratio of dividends per share to earnings per share
$TradCont_i$	Percentage of months in the respective time-series with non-zero returns
$ln\_RelTradVol_i$	Natural logarithm of number of shares traded for a stock divided by total number of shares
EP_D_i	Dummy that is 1 if earnings are negative in any year of the 5-year period, otherwise 0
$EarningsPrice_i$	Earnings per share divided by closing price if earnings are positive, otherwise 0
$BookMarket_i$	Balance sheet value of ordinary equity divided by market value of ordinary equity

Source: Rothballer and Kaserer (2012a)

sector reforms globally) is suspected. Therefore, I follow Arellano (1987)'s suggestion to use higher-level clustering and apply it on the country level as sector correlation is taken care of by the sector dummies.[13]

For the purpose of this analysis the listed infrastructure firm sample is reduced, as companies from countries or sectors for which no regulation data are available drop out. For example, all cable and satellite firms are excluded from the original sample and firms from countries such as Bahrain, Bangladesh, Croatia, Estonia, Hungary, Kuwait, Morocco, Saudi Arabia, and Vietnam are excluded. As depicted in Table 4.7 these countries contribute less than 5 firms to the overall sample. The resulting sample consists of 764 companies that originate from 46 countries and operate in the following infrastructure sectors: Telecommunication (wireless, fixed-line), transport (airports, pipelines, ports, railways, highways), and utilities (generation, transmission and distribution of electricity, gas and water). Table 6.2 provides an overview of the number of firms by sector and region. Table 6.3 shows the descriptive statistics for all the used independent and dependent variables.

[13]Inter-cluster correlation becomes negligible as the mean of the sector impact is removed from the error term.

Table 6.2: Number of infrastructure firms by sector and region

	North America	Latin America	Western Europe	Eastern Europe	Africa, Middle-East	Asia-Pacific	World
Infrastructure	190	90	159	18	3	304	764
Telecommunication	54	17	37	3	2	32	145
Transport	21	9	24	0	0	63	117
Utilities	115	64	98	15	1	209	502
Wireless	21	7	20	2	2	30	82
Fixed-line	33	10	17	1	0	2	63
Airports	0	3	8	0	0	7	18
Ports	0	1	2	0	0	11	14
Highways	0	3	4	0	0	22	29
Railroads	6	1	5	0	0	15	27
Pipelines	15	1	5	0	0	8	29
Electricity	40	50	59	13	1	130	293
Water	15	6	11	0	0	20	52
Gas	25	7	5	1	0	38	76
Multi	35	1	23	1	0	21	81

Source: Rothballer and Kaserer (2012a)

Table 6.3: Descriptive statistics: Regression variables

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Local Beta	764	0.749	0.506	0.008	4.894
Asset Beta	764	0.505	0.349	0.005	3.333
FirmValue	764	8.881	22.476	0.005	220.633
SalesGrowth	764	0.171	0.291	-1.419	3.110
Leverage	764	0.980	1.774	0.000	20.956
DivPayout_D	764	0.785	0.411	0.000	1.000
DivPayout	764	0.393	0.472	0.000	7.909
TradCont	764	0.970	0.086	0.143	1.000
RelTradVol	764	0.160	1.302	0.000	35.355
EP_D	764	0.305	0.461	0.000	1.000
EarningsPrice	764	0.049	0.228	0.000	6.207
BookMarket	764	0.717	1.585	0.000	41.667
CountryGovernance	764	0.631	0.838	-1.076	1.862
MarketCompetition	764	2.352	1.778	0.000	6.000
PriceRegulation_D	764	0.621	0.353	0.000	1.000
IncentiveRegulation_D	764	0.331	0.442	0.000	1.000
IndependentIncentive_D	764	0.110	0.241	0.000	1.000
Independence_D	764	0.490	0.403	0.000	1.000

Note: Firm value in $ billion. Regulatory variables not centered around the mean. All variables that are logged in the model, are non-logged in this table.
Source: Author

6.3 Empirical results

6.3.1 Price regulation

This following sections present the empirical results with regard to the impact of price regulation, the regulatory regime, and regulatory independence on market risk. The outputs of the estimated regressions are depicted in Table 6.4. The two left columns show the results for the standard specification for equity beta and asset beta as dependent variable using the full sample. To test for a model misspecification, the two right columns show the results for alternative regression models: A model without sector dummies and a model with country dummies instead of region dummies and country-specific controls. In addition, Table 6.5 contains the estimates for various robustness tests using alternative datasets in the following order: Subsample of OECD countries only (since data for non-OECD countries are manually assembled); sample with alternative dummy definitions[14] (since some dummies contain discretionary assumptions); sample including negative betas; sample where outliers[15] in the variables are dropped. Hence, the underlying number of observations varies in these latter models.

The regression results uniformly lend support to Peltzman (1976)'s buffering hypothesis (H2.1). In the standard model, equity betas of firms that are fully price regulated are significantly (at the 95% significance level) reduced by 0.248 in comparison to unregulated firms. Partially regulated firms fall in between with a beta of 0.124 lower than unregulated companies. Asset beta is also significantly reduced by 0.115 for price regulated firms (at the 90% significance level). None of the robustness tests violates this finding. When reducing the sample to OECD countries only the results are reinforced by the highly significant coefficient of -0.326. The above observations are also maintained when excluding sector dummies, using

[14]The alternative dummy variable definitions assume a dummy value of 0.75 instead of 0.5 for partial price regulation and an alternate procedure for calculating *Independence*. Setting the value for partial price regulation to 0.25 is also tested and does not affect the results relative to the standard model. Hence, the result is not reported.

[15]Outliers are defined as being 4 times the standard deviation apart from the respective mean.

country instead of region dummies, modifying the dummy definitions, including negative betas, and excluding outliers in the dependent and independent variables. In these five specifications, betas are reduced by between 0.216 and 0.257 at high significance levels. In summary, the data provide strong support for the buffering hypothesis that price regulation reduces systematic risk.

6.3.2 Regulatory regime

In the standard specification, the stand-alone effect of incentive regulation relative to cost-based regulation is insignificant with a coefficient of 0.044, contradicting H2.2. The coefficient is also positive across all robustness specifications, but never significant. In contrast, the interaction term between incentive regulation and independent regulation is significantly positively correlated with market risk. In the standard model as well as in the specifications using asset beta, no sector dummies, OECD countries only, alternative dummy variable definitions, including negative betas, and excluding outliers the coefficient estimates for the interaction term range between 0.190 and 0.339, being mostly significant at the 10% level (and on the 5% level for the models without sector dummies and including negative betas). Only when substituting the regional dummies for the country-specific dummies, this conclusion cannot be supported as *IndependentIncentive* becomes insignificant with a coefficient of 0.065. While multicollinearity is modest across all previous models with the maximum variance inflation factor (VIF) being below 3, the latter model suffers from collinearity between the country dummies and regulatory independence as institutional foundations of regulators are correlated across sectors in a given country (VIF $>$ 4). This is particularly true for utilities and telecommunication which account for a large share of the sample. This model is less suited for the given analysis objective as the country dummies capture the variation that *IndependentIncentive* is supposed to explain. In summary, the results indicate that incentive regulation implemented along with an autonomous regulator increases systematic risk, whereas firms enjoy a soft regulatory treatment with lower risk when governments wield influence over regulatory decisions under incentive regimes. This implies that only for independent regulators a significant difference between incentive and cost-based regulation articulates in terms of systematic risk. For government regulators there is no difference between the two regulatory regimes.

6.3.3 Regulatory independence

The regression results confirm hypothesis H2.3 on the relationship between independent regulators and market risk. The presence of an independent regulatory authority reduces systematic risk by 0.161 in the standard specification at the 95% significance level. While the coefficient is slightly smaller when asset beta is used as dependent variable (-0.091), it is even higher (and significant at the 99% level) for OECD countries only (-0.289). The further robustness tests also strongly support this finding as across all specifications the magnitude of the coefficient for equity betas varies between -0.141 and -0.155. These coefficient results ranging between 0.15 and 0.30 imply a cost of capital premium of about 90 to 180 basis points (assuming a 6% market premium, ceteris paribus), if independent regulators are not institutionalized. For both incentive and cost-based regulation the presence of a political regulator commands a risk mark-up relative to regulation by bureaucrats. However, for incentive regimes, the premium from effective incentive regulation under independent regulation (represented by the interaction term of about 0.3) outweighs the mark-up of a government regulator (about 0.15).

Table 6.4: Regression results: Regulation and systematic risk

	Local Beta Full Sample	Asset Beta Full Sample	Local Beta Ex Sector DVs	Local Beta Country DVs
ln_FirmValue	0.000	0.008	-0.001	-0.014
	(0.969)	(0.387)	(0.892)	(0.157)
SalesGrowth	0.142	0.103 **	0.162	0.146
	(0.145)	(0.037)	(0.113)	(0.155)
ln_Leverage	0.046 ***	-0.061 ***	0.035 ***	0.044 ***
	(0.003)	(0.000)	(0.007)	(0.000)
DivPayout_D	-0.199 **	-0.137 **	-0.212 **	-0.190 ***
	(0.038)	(0.012)	(0.039)	(0.004)
DivPayout	-0.180 **	-0.116 **	-0.186 **	-0.171 ***
	(0.020)	(0.022)	(0.014)	(0.000)
TradCont	0.386	0.253 *	0.361	0.609 **
	(0.125)	(0.093)	(0.127)	(0.049)
ln_RelTradVol	0.023 *	0.016 **	0.023 **	0.051 ***
	(0.055)	(0.032)	(0.042)	(0.000)
EP_D	0.075	0.026	0.080 *	0.108 **
	(0.127)	(0.432)	(0.095)	(0.025)
EarningsPrice	-0.048	-0.035	-0.057	-0.041
	(0.200)	(0.293)	(0.144)	(0.275)
BookMarket	-0.008 **	-0.003	-0.008 **	-0.013 ***
	(0.018)	(0.300)	(0.045)	(0.003)
CountryGovernance	-0.142 ***	-0.105 ***	-0.130 ***	
	(0.002)	(0.000)	(0.007)	
MarketCompetition	-0.032 *	-0.023 *	-0.019	
	(0.064)	(0.070)	(0.326)	
PriceRegulation_D	-0.248 **	-0.115 *	-0.238 **	-0.244 ***
	(0.027)	(0.062)	(0.013)	(0.000)
IncentiveRegulation_D	0.044	0.010	0.056	0.049
	(0.385)	(0.781)	(0.296)	(0.443)
IndependentIncentive_D	0.313 *	0.190 *	0.339 **	0.065
	(0.057)	(0.064)	(0.029)	(0.611)
Independence_D	-0.161 **	-0.091 **	-0.150 *	-0.141 *
	(0.010)	(0.015)	(0.051)	(0.066)
Constant	1.554 ***	0.851 ***	1.230 ***	0.906 ***
	(0.000)	(0.000)	(0.000)	(0.002)
N	764	764	764	764
Adj. R-square	29%	30%	26%	35%

Note: The table reports OLS coefficient estimates and p-values based on clustered standard errors (in parentheses). ***, ** and * indicate statistical significance at the 1%, the 5%, and the 10% levels (two-tailed), respectively. Coefficients for sector, region, and country dummy variables are not reported. DV = dummy variable.
Source: Rothballer and Kaserer (2012a)

Table 6.5: Robustness test: Regression results for alternative datasets

	Local Beta OECD Countries	Local Beta Alternate DVs	Local Beta No Neg. Beta	Local Beta Ex Outlier
ln_FirmValue	-0.004	0.003	0.008	0.000
	(0.796)	(0.807)	(0.517)	(0.996)
SalesGrowth	0.067	0.157	0.154 *	0.266
	(0.513)	(0.105)	(0.090)	(0.150)
ln_Leverage	0.048 ***	0.044 ***	0.042 ***	0.048 ***
	(0.004)	(0.004)	(0.007)	(0.003)
DivPayout_D	-0.351 ***	-0.204 **	-0.233 **	-0.199 **
	(0.000)	(0.033)	(0.013)	(0.012)
DivPayout	-0.118 ***	-0.179 **	-0.172 **	-0.172 **
	(0.009)	(0.020)	(0.033)	(0.017)
TradCont	0.449	0.377	0.622 **	0.257
	(0.249)	(0.124)	(0.037)	(0.611)
ln_RelTradVol	0.046 ***	0.024 **	0.044 ***	0.026 **
	(0.007)	(0.048)	(0.000)	(0.050)
EP_D	0.092 *	0.077	0.035	0.044
	(0.067)	(0.114)	(0.402)	(0.425)
EarningsPrice	-0.031	-0.041	-0.038	-0.435
	(0.413)	(0.277)	(0.303)	(0.537)
BookMarket	-0.011 ***	-0.008 **	-0.004	0.038
	(0.001)	(0.021)	(0.296)	(0.380)
CountryGovernance	-0.199 ***	-0.132 ***	-0.123 **	-0.144 ***
	(0.001)	(0.002)	(0.014)	(0.001)
MarketCompetition	-0.032 *	-0.031 *	-0.024	-0.034 **
	(0.080)	(0.077)	(0.186)	(0.046)
PriceRegulation_D	-0.326 **	-0.236 **	-0.216 *	-0.257 **
	(0.013)	(0.021)	(0.056)	(0.025)
IncentiveRegulation_D	0.086	0.053	0.038	0.036
	(0.215)	(0.304)	(0.465)	(0.510)
IndependentIncentive_D	0.278 *	0.289 *	0.342 **	0.275 *
	(0.061)	(0.067)	(0.043)	(0.090)
Independence_D	-0.289 ***	-0.155 ***	-0.148 **	-0.148 **
	(0.006)	(0.006)	(0.033)	(0.025)
Constant	1.761 ***	1.499 ***	1.248 ***	1.675 ***
	(0.000)	(0.000)	(0.000)	(0.001)
N	472	764	787	742
Adj. R-square	36%	29%	26%	29%

Note: The table reports OLS coefficient estimates and p-values based on clustered standard errors (in parentheses). ***, ** and * indicate statistical significance at the 1%, the 5%, and the 10% levels (two-tailed), respectively. Coefficients for sector and region dummy variables are not reported. DV = dummy variable.
Source: Adapted from Rothballer and Kaserer (2012a)

6.3.4 Other variables

The regression models are capable to explain between 26% and 36% of the variations in systematic risk, matching the R-squared found by Gaggero (2012) in a similar approach. The models' appropriateness is reinforced by the fact that all control variables show the expected sign and are mostly significant – with similar results as in section 5.3.5. Sales growth is positively correlated with risk indicating the uncertainty about future earnings of growth stocks and their exposure to the economy. As expected, higher financial leverage entails higher market risk. Firms that pay dividends at all or disburse more are less risky as dividends constitute certain cash earnings and signal positive corporate prospects. While trading continuity is mostly insignificant, a higher relative trading volume entails higher betas as actively traded stocks follow markets more closely. The intuition that unprofitable companies are riskier is confirmed by the positive earnings dummy. The impact of book-to-market is negative, since stocks with a low Tobin's Q are characterized by less risk as their underlying value is less dependent on expectations. The coefficient for the quality of country governance is consistently negative and highly significant. Besides the sector-specific regulatory framework, the country-specific institutional environment also seems to matter for the risk exposure of infrastructure assets. Consequently, the effectiveness and stability of the political institutions play an important role for the risk exposure of infrastructure investors due to the pervasive government interventions in infrastructure. In fact, Preqin (2011) shows that most infrastructure investors prefer to invest in developed countries with 47% of investors targeting European assets and 36% focusing on North American infrastructure as those carry less political risk compared to emerging markets. As generally hypothesized, entry barriers also tend to reduce systematic risk as all coefficients are negatively significant.

6.4 Discussion

6.4.1 Price regulation: Peltzman revisited

In accordance with most previous studies (e.g. Binder and Norton (1999), Chen and Sanger (1985), Fraser and Kannan (1990), Sidak and Ingraham (2003)), the empirical evidence in section 6.3.1 supports Peltzman (1976)'s hypothesis (H2.1) that price regulation reduces market risk. This buffering effect is shown to hold for a global sample of firms from both developed and emerging countries and across all infrastructure sectors including telecommunication, transport, and utilities. To the best of my knowledge, this is the largest set of jurisdictions and industries for which this theory is confirmed. While previous studies are mostly based on datasets from the 1970s to 1990s, this is the first study to reaffirm the buffering hypothesis for firms operating in an increasingly competitive and liberalized market environment. The finding reaffirms Peltzman (1976)'s idea that regulators act counter-cyclically by favoring producers in economic contractions while shielding consumers from price increases during expansions. This fact implies that firms are granted positive economic profits since prices are set between the monopoly and the competitive price. The finding also emphasizes that risk is endogenous to regulation. Observed measures of systematic risk should be used cautiously when calculating the cost of capital during regulatory procedures (Norton (1985)). Any novel regulatory rules or liberalization proposals need to be considered appropriately in the determination of the cost of capital and the regulated prices.

6.4.2 Regulatory regime: Incentive regulation and regulatory capture

The empirical results in section 6.3.2 show that incentive regulation alone does not significantly impact systematic risk. This result is in line with Gaggero (2007) and Gaggero (2012), though different regulatory data sources, a larger and more heterogeneous sample, and a cross-sectional instead of a panel approach are employed.

However, incentive regulation established jointly with an autonomous regulator results in higher risk, confirming Alexander et al. (1996) and Grout and Zalewska (2006). The latters' analysis actually uses a dataset of U.K. utilities which operate under a mature regulatory framework with a strong institutional foundation of independence. For this reason, my research contributes to the literature by highlighting the interdependence between the regulatory regime and a coherent policy framework. This result is also in accordance with Égert (2009)'s finding that only incentive regimes accompanied by an independent regulator have a positive effect on infrastructure investments.

The finding suggests that the objectives of incentive regulation, namely transferring risks onto firms in order to create efficiency incentives, seem not to materialize when regulators are politically entrenched. The fact that risk is effectively not shifted onto firms has crucial implications. The desired level of cost containment is not accomplished as firms do not face the risk and rewards of these operational improvements – opposing the original intention of incentive regulation to shift cost accountability to firms. As a consequence, output prices may be inefficiently high and economic welfare is surrendered. Instead, the risk accrues at the consumer level, similar to cost-based regulation. As a result, there may arise a danger of privatizing benefits while socializing risks, which could undermine public support for private infrastructure ownership (Strong et al. (2004)).

The finding of ineffective incentive regimes under government regulation may be attributed to regulatory capture. Regulatory capture is a form of government failure that occurs when a regulatory agency advances the special interests of the producer instead of acting in the public interest. The origins of regulatory capture include both information asymmetries and regulatory gaming. First, regulators with insufficient capabilities and resources may not be able to resolve the information asymmetries between regulators and firms (Baron and Myerson (1982)). Secondly, the factual regulatory gaming behavior of wealth maximizing firms and power-maximizing politicians might cause regulatory capture.

Information asymmetries between regulators and firms are particularly pronounced for incentive regimes as this regulatory mechanism requires higher technical demands than cost-based regulation. The regulator needs to gauge the operator's efficiency level and stipulate an adequate X-factor taking into account what a reasonably efficient benchmark firm would require to cover its operating costs and capital investments for increasing capacity, reducing environmental impact, or improving service quality. Since the regulator is not able to observe the firm's costs and its feasible set of investments, the arising information asymmetry undermines the accuracy and appropriateness of the efficiency targets. In fact, in Kirkpatrick et al. (2004)'s survey of regulators in developing and transition countries, 96% of respondents complain about information asymmetries under incentive regulation in comparison to 59% under rate-of-return regulation.

Information asymmetries are exacerbated by the factual strategic gaming behavior of firms. In incentive regulation, a firm that performs superior to the assumed benchmark is allowed to retain the excess savings until the next regulatory review. Consequently, the management wants the benchmark for the forthcoming control period to be as soft as possible, and has an incentive to manipulate the regulator's expectation on future performance. This skews management objectives to actually influence the regulator in the price setting process by providing misleading information or overly pessimistic forecasts and thus to abuse the information asymmetries and extract an undue economic rent. For example, the regulated firm will take advantage of this situation by delaying or concealing cost saving investments until the start of a new control period. Companies supervised by unsophisticated regulators may also be able to cut their operating costs below the minimum efficiency assumption by undetectably deteriorating service quality. As a result, management devotes much time and effort to manage their regulator instead of improving firm performance. But regulators must rely on the company's data or establish their own projections based on benchmarking or analysis of financial and operational performance metrics. In fact, many regulators criticize firms for giving misleading information when incentive regulation is applied (Kirkpatrick et al. (2004)). Jamasb et al. (2003) alludes to the fact that even under yardstick regulation –

which is meant to eliminate information asymmetries – possibilities of regulatory gaming abound as firms exploit the discretionary leeway in benchmarking models, cost/asset allocation, and data disclosure.

In addition, firms may pursue political lobbying to capture politicians by offering direct monetary support or indirect political support by influencing voters through lobbying activities. For example, Strong et al. (2004) and Kirkpatrick et al. (2004) observe political and firm pressure on regulatory bodies during price setting processes in various emerging countries, particularly in Latin America. The desire to influence politicians, yet hiding that fact from voters and customers, is also documented by the opaqueness of U.S. utilities. They show the lowest propensity among all surveyed industries in disclosing their political donations (Robert Zicklin Center (2011)).[16] These efforts to influence the price setting under incentive regulation may be effective as regulators enjoy considerable discretion in determining prices. Though the initial intention of Littlechild (1983) was to avoid regulatory capture in incentive regulation by instituting a simple monitoring mechanism for the intra-period price adjustments[17], the inter-period reviews provide ample scope for strategic firm behavior and discretionary leeway on side of the regulator. For example, Gaggero (2012) cites Alliant Energy[18] in being successful in influencing its regulator – whose board is appointed by the local governor – after filing several rate increase requests despite being subject to a price freeze.

Independent regulatory authorities mitigate the above described effects of strategic firm and politician behavior as well as information asymmetries. They may perform superior in avoiding regulatory capture as they are less exposed to conflicts of interest. They do not require political support for staying in office and they do not need to enhance their chance for future industry employment as they

[16]Data are based on the Baruch Index of Corporate Political Disclosure by the Robert Zicklin Center for Corporate Integrity at Baruch College. This index measures the transparency of all S&P100 corporations about their policies and practices of corporate giving along 57 dimensions.

[17]Littlechild (1983) hoped that the scheme would be temporary until competition would be ensured.

[18]Alliant Energy is a utility supplying gas and electricity in Wisconsin and Minnesota.

have stable career prospects within the regulatory function, lessening the impact of the "revolving doors" phenomenon (Dal Bo (2006)). In addition, they are not reliant on financial support from firms or governments since they have revenue source independent from the national budget and adequate personal income reducing the scope for corruption. But other factors of regulatory quality besides regulatory independence may also play a significant role in overcoming information asymmetries (Andres et al. (2007)). Independent regulators are more frequently equipped with sufficient financial resources enabling them to attract and retain competent staff and to continuously invest in knowledge through training and research. They can offer attractive, long-term career opportunities since positions are independent from the ruling political party. Hence, they can develop the specialist competences that are indispensable for gauging the reliability of data provided by firms or for establishing own appraisals of efficiency and required investments. They also dispose of significant accumulated regulatory experience and established processes and systems as they often evolved from previous regulatory institutions. In summary, independent regulators may be in a better position to resolve information asymmetries and regulatory gaming situations, whereas politically dependent regulators may lack the required capabilities and resources to adequately implement incentive regulation. Hence, firms are less successful in lessening the restrictions of incentive regulation when regulators are independent from the political system as those are less likely to fall prey to regulatory capture.

6.4.3 Regulatory independence: Benefits of commitment

The empirical results do not only emphasize the relevance of independent regulators in rendering incentive regulation effective, but the fact that independent regulation reduces systematic risk also provides evidence for its benefits in reducing regulatory uncertainty. The results in section 6.3.3 suggest that private firms require a mark-up for the regulatory risk of unanticipated government actions which could adversely affect the net present value of their assets. As politically entrenched regulators are often influenced by political opportunism, they may implement regulatory policies that harm firm interests in exchange for political gains. In contrast, "at arm's length" regulators seem to signal and implement continuous regulations. They are better equipped to overcome the commitment (or hold-up) problem arising from the time inconsistency between election cycles and the payback duration of infrastructure investments as they can credibly self-commit and adhere to a stable policy objective. They are also able to withstand the pressure from interest groups because they are less reliant on political support for staying in office or for future employment opportunities. Hence, their regulatory decisions are likely to be based on clear and stable rules, a well-defined decision making process and objective criteria, and a professional interpretation of laws and rules free of political considerations. Moreover, contracts may be more complete when independent regulators are present since more diligence and resources are used for the institutional and policy design as well as for the continuous rate setting procedures. It is important to note that the politicians' failure to commit is not a matter of shifting risk between stakeholders. Regulatory risk vanishes when independent regulators are established. This entails lower cost of equity, possibly translating into more investments, lower consumer prices, and higher social welfare.

Since no study has yet analyzed the direct impact of regulatory independence on risk, this finding is a new contribution to the literature. It is consistent with other studies that demonstrate the beneficial impact of independent regulation on other regulatory outcomes such as investments (Wallsten (2001), Gutiérrez (2003), Guasch et al. (2007), Bortolotti et al. (2011), Cambini and Rondi (2011)). The finding also reinforces Barcelos and da Silveira Bueno (2010)'s observation of significant regulatory risk in Brazilian infrastructure firms caused by the strong political involvement and legal uncertainty. In fact, according to the collected regulatory data all Brazilian regulators (except for telecom) are not fully independent institutions as they face strong influence from the respective ministry.

6.4.4 Policy and investor implications

The presented findings give rise to the conclusion that a possible regulatory failure prevails if infrastructure firms are directly regulated by governments. It appears that firms subject to incentive regulation neutralize the intended risk allocation of this regime if the regulator is not independent. If a coherent framework with independent regulatory institutions that are able to handle the advanced requirements of incentive regulation is absent, the ex-ante policy objective to transfer manageable risks onto infrastructure firms and to create incentives for cost efficiency, may not be realized. The favorable regulatory treatment may be achieved by capturing the discretionary decision making process embedded in incentive regulation. Depending on the firm's leeway for strategic behavior and its bargaining power, as well as the degree of information asymmetries and the benevolence of the regulator, firms are able to shift cost risks onto consumers. Therefore, if incentive regulation is to be applied effectively with its associated benefits, it needs to be implemented along with independent and sophisticated regulators that are able to avert regulatory capture, i.e. overcome the information asymmetry and regulatory gaming and lobbying by informationally- and resource-advantaged firms. The evidence also suggests that independent regulators curb regulatory opportunism. They reduce regulatory uncertainty and opportunism by implementing continuous regulations and credibly signaling commitment to sunk cost recovery and an adequate return on capital.

These findings have relevant implications for investment management. Investors need to develop specific skills to appreciate the impact of the regulatory system on their cost of capital and the economic viability of investment projects. Factors such as the scope of price regulation, the strength of incentives and thus the transferred risks under the specific regime, and the anticipated strictness and continuity of the implemented regime have to be considered. A profound understanding of these factors may yield a significant competitive advantage relative to other investors.

The results also have considerable policy implications with regard to effective infrastructure regulation. Legislators may push forward institutional reform in the direction of an enhanced independence of regulatory authorities and advance the regulators' capabilities and resources. First, reforms shall transform regulators into truly – de-facto and de-iure – independent institutions by assigning expansive and flexible decision rights that minimize political interference. This includes competences in terms of rule making, sanctioning firms' misbehavior and the possibility to use arbitration and appeal procedures. Secondly, regulators need to be strengthened with technically trained and sufficient staff as well as a stable monetary endowment independent from the national budget. An additional long-term policy option that becomes apparent from the above results, besides the short-term sector-specific regulatory reform, is to embark on a long-term effort to improve the country-wide institutional, legal, and political environment which would lower the cost of equity for infrastructure firms.

The benefits of implementing this reform agenda of autonomous regulators would be twofold: On the one hand, it would increase the effectiveness of incentive regulation, which increasingly is becoming the preferred mode of price regulation. On the other hand, fostering regulatory commitment reduces regulatory uncertainty and thus the cost of capital for firms. By impairing regulatory capture and regulatory opportunism, the proposed policy direction contributes to achieving higher operational efficiency and welfare gains. In many developed countries and in certain sectors (e.g. telecommunication) the idea of regulatory independence has already been mainstreamed. However, in emerging markets and in the transport sector progress is insufficient. For example, Estache and Goicoechea (2005b) document that only 66%, 51%, and 21% of the developing countries have an independent regulator for the telecoms, electricity, and water and sanitation sectors as of 2004. Moreover, many of today's formally independent regulators are insufficient for creating a more effective and less opportunistic regulatory environment, as politicians de-facto retain substantial regulatory policy levers. Increased efforts should be made on side of international agencies and donors to attenuate the capacity constraint faced by the poorest countries (Estache and Fay (2007)), where private capital is lacking due to cost of capital premiums relating to regulatory and political risk (Sirtaine et al. (2005)) and where infrastructure spending is insufficient (Fay and Yepes (2003)). Besides independent regulators, investors need to perceive the political will and societal accordance that politicians will not take over the reign of regulation once problems or dissatisfaction unfold.

6.4.5 Limitations

The findings of this analysis are limited both by the scope of the used dataset and the depth of the analysis. The dataset is limited in terms of certain sectors, though it is the most comprehensive infrastructure and regulation dataset yet analyzed. It only has a cross-sectional dimension ignoring the inter-temporal dimension which may yield further insights and more robust findings. The infrastructure dataset only represents listed infrastructure firms which may not represent all infrastructure assets due to their specific financial and governance structures. The industry scope is confined to economic infrastructure. Thus, further studies are required to analyze the impact of regulation for social infrastructure and PPP projects.

Regulation is a complex phenomenon which is difficult to capture in a few variables. The details of the regulatory framework and the actual implementation of these rules under real world constraints strongly influence the regulatory outcome. For example, some firms that are subject to price regulation may offer their service at prices below the regulated prices, effectively rendering price regulation ineffective. This is the case in some telecommunication markets where wireless competition forces fixed-line incumbents to lower their prices despite higher regulated prices. Moreover, additional micro-level regulatory variables, such as the detailed features of the regulatory regime (e.g. regulatory lags, quality standards, universal service obligations), the regulators' financial and staff resources, and a distinction between de-facto and de-iure independence may provide interesting results. Further research may either explicitly capture these confounding factors as quantitative variables or try to disentangle their impact using case study analyses.

6.5 Synopsis

In this chapter, I analyze the impact of price regulation, the regulatory regime, and regulatory independence on market risk. First, I reaffirm Peltzman (1976)'s buffering hypothesis that price regulation significantly reduces systematic risk, complementing the large body of empirical analyses on this theory, for this cross-country, cross-sector sample of infrastructure firms operating in an increasingly competitive and liberalized market. Second, contrary to some previous publications, the theoretical expectation that incentive regulation positively affects market risk relative to cost-based regulation is confirmed, but only if incentive regulation is implemented along with an autonomous regulator. Only independent regulators appear to impose additional risk onto firms under incentive in comparison to cost-based regulation. Politically entrenched regulators, on average, seem not to effectively resolve the information asymmetries and regulatory gaming situations arising in incentive regulation, and thus may fall prey to regulatory capture. As a result, the intended consequences of incentive regulation, i.e. to transfer manageable cost and demand risks onto producers with the aim to create powerful cost reduction incentives, may not materialize. Third, I find that autonomous regulators reduce the market risk of infrastructure firms by curbing regulatory opportunism and fostering continuity and commitment in price setting. When regulators are dependent, producers have to bear higher regulatory uncertainty, translating into higher cost of capital and possibly higher prices at the expense of consumers.

Future policy reforms should be directed towards furthering the independence and endowments of regulatory authorities to (1) enable the intended risk allocation and cost awareness of incentive regimes by alleviating regulatory capture, and to (2) reduce the regulatory risk (and cost of capital) based on improved regulatory commitment. Given the prevalence of de-iure (and de-facto) dependent regulators and the significant regulatory powers wielded by national governments, this finding raises concerns about the effectiveness of regulatory institutions and policies in network industries around the world. This is of particular relevance to emerging countries and transportation sectors, where institutional reforms are lagging behind. To address the above two problems, policy makers should strive to further the competences of regulators towards truly independent institutions. This involves both an institutional set-up free of political interference and an adequate level of funding and staffing independent from the national budget and political considerations. The relevance of this finding is compounded by the massive infrastructure requirements in both emerging and developed countries. Resource-constrained governments are unlikely to provide sufficient finance for the projected construction and maintenance needs. Instituting independent regulators would contribute to attracting private capital by lowering capital costs and, in addition, would improve economic efficiency by creating more effective risk transfer mechanisms.

Chapter 7

The Inflation Hedging Properties of Infrastructure

In this chapter the inflation hedging properties of investments in infrastructure are analyzed empirically. First, the often cited hypothesis that infrastructure provides an enhanced inflation hedge is introduced. Next, the infrastructure index construction approach, the inflation data, and the regression methodology are presented. Empirical results are first provided for domestic infrastructure overall, followed by each infrastructure sector individually, and finally for different portfolios of high and low pricing power infrastructure. The chapter concludes with a discussion of the findings, the implications for investors, and an outlook on future research. This chapter is based on joint work with Maximilian Rödel (Rödel and Rothballer (2011), Rödel and Rothballer (2012)).

7.1 Motivation

After two decades of historically low inflation rates across most developed countries, the current economic environment in the wake of the global financial crisis is considered a perfect breeding ground for inflation by many economists and analysts.

The central banks' monetary policies of low interest rates and extensive quantitative easing schemes, have contributed to a rapid expansion of the monetary base. At the same time, the public stimulus packages have fueled sovereign debt levels and raised fears that governments may be tempted to inflate these away. In addition, rebounding commodity prices and lower expected productivity gains after an abating impact from information technology are contributing to the expectation that inflation may return.

Though some arguments such as the significant slack in the economy in the form of high unemployment and idle production capacity point to a deflationary scenario, inflation concerns have gained momentum and are back on the agenda of politicians, corporate leaders as well as institutional and private investors. Irrespective of which economic scenario will eventually unfold, investors worry about how to prepare their portfolios for inflation in order to preserve purchasing power. Among traditional asset classes real estate, equities (in the long-run) and commodities are generally good inflation hedges, while cash and bonds are negatively affected by inflation.[1]

Besides the traditional asset classes, investors increasingly seek exposure to alternative assets such as infrastructure with the objective to hedge against inflation, which is of particular concern for insurance companies and pension funds due to their long-term obligations. The Californian pension fund CalPERS, for example, commits $2.5 billion to infrastructure under its inflation-linked asset class allocation (Page et al. (2008)). The investors' desire to earn an absolute return above inflation from their infrastructure commitments is also manifested in the inflation-linked return benchmarks that are employed by many infrastructure funds (Probitas Partners (2007), Inderst (2009)).

In the investment community, the ex-ante claim that infrastructure provides inflation-linked returns is regularly justified by its real asset characteristic, monopolistic market positions, favorable regulatory regimes (e.g. RPI-X), and the modest input price exposure as outlined in section 3.3.1. However, empirical studies on the inflation hedging properties of infrastructure are limited in quantity and quality as

[1]Refer to Attie and Roache (2009) for a recent literature survey.

reviewed in section 3.3.2. This analysis contributes to the emerging literature on the investment characteristics of infrastructure by comparing the inflation hedging features of listed infrastructure and equities as proposed by Amenc et al. (2009). It additionally adds to the established literature on the inflation hedging qualities of different asset classes by extending the evidence to infrastructure. This is the first analysis that investigates the inflation hedging features of infrastructure in a comprehensive and methodologically robust study by testing the following hypothesis using a sufficiently long time series across multiple countries:

H3.1: Listed infrastructure hedges inflation better than other public equities

7.2 Methodology

7.2.1 Equity and infrastructure indices

Previous analyses of the inflation hedging properties of infrastructure have mostly relied on the publicly available indices for listed infrastructure. Yet, these only cover relatively short time series, as outlined in Table 7.1. The index with the longest history – the UBS Global Infrastructure – only extends back to 1995. Empirical

Table 7.1: Public infrastructure indices

Index	**Start date**	**Firms**
UBS Global Infrastructure & Utilities	1995, September	243
MSCI World Infrastructure	1998, December	153
NMX30 Infrastructure Global	1998, December	30
Macquarie Global Infrastructure	2000, July	243
INFRAX	2000, September	50
S&P Global Infrastructure	2001, November	75
Dow Jones Brookfield Global Infrastructure	2002, December	85

Source: Rödel and Rothballer (2011)

evidence based on indices with such limited coverage is prone to biases as the 1990s and 2000s recorded historically low inflation rates. In addition, only few infrastructure indices are available on a country level. Hence, most of them lump domestic and international assets together which leads to an inherent overstatement of the inflation hedging quality due to exchange rate moderation effects. For these reasons, country-specific return indices are self-constructed from individual infrastructure firms as proposed by Amenc et al. (2009). For this purpose, I employ the sample of 1,458 listed infrastructure firms introduced in chapter 4, including all sectors of economic infrastructure (transport: ports, airports, pipelines, railways, highways; utilities: generation, transmission and distribution of electricity, gas and water; telecommunication: fixed-line, mobile, satellite, cable).

As the inflation hedging characteristics of infrastructure need to be compared against a benchmark, MSCI country indices in local currency are used to proxy comparable equity returns. The equity index data are retrieved through Global Financial Data (GFD) for the years 1973 till 2009 as described in section 4.5.4.[2] The GFD data are provided in a consistent manner across a long time series as disruptive macroeconomic events are corrected in a way as they would have impacted an investor. As these MSCI equity indices are constructed according to a set of rules, the infrastructure indices need to be derived by applying a comparable methodology. To make the two indices consistent, they have to be aligned in terms of return type, index weighting and re-balancing, country and sector scope, trading liquidity, and survivorship bias.

Since the MSCI equity indices are total return indices (in contrast to price indices), the return data for each infrastructure index constituent are based on the Thomson Datastream code Return Index (RI) as introduced in section 4.4. This data item incorporates both capital appreciation and cash dividend yields and also properly accounts for capital structure changes.[3] Next, the nominal infrastructure return indices $R^n_{c,t}$ (expressed as continuously compounded returns) for each country c are computed by applying market value weighting and performing an annual

[2]The data for equity indices are available back until 1949, but the retrieved time series is limited by the historic availability of infrastructure data.

[3]Note, that return data are cleansed by applying the screens advocated by Ince and Porter (2006) as described in section 4.4.2. This procedure eliminates biases arising from data errors in TDS including data unavailability, rounding errors, and unrealistic returns.

index rebalancing as of 31st December analogous to the MSCI index methodology:

$$R^n_{c,t} = ln\left(\sum_{i=1}^{N}\left(\frac{EquityMV_{i,t-1}}{\sum_{i=1}^{N} EquityMV_{i,t-1}}(e^{R^n_{i,t}} - 1)\right) + 1\right)$$

where $R^n_{i,t}$ is the nominal annual return of infrastructure firm i in year t with continuous compounding, $EquityMV_{i,t-1}$ the market capitalization of infrastructure firm i at the end of year $t-1$ (i.e. at the beginning of year t), $\sum_{i=1}^{N} EquityMV_{i,t-1}$ the cumulated market capitalization of all infrastructure index constituents, and N the total number of infrastructure firms that fit the specific index definition in terms of country c, liquidity, and size (and possibly industry in case of sector-specific indices).[4] These domestic infrastructure indices are calculated for each country individually using the local currency returns of all companies with headquarters in the respective country and listed on the local stock exchange. The infrastructure indices are also split into sector indices for telecommunication, transport, and utilities.[5]

Similar to MSCI equity indices, illiquidly traded shares are excluded from the constituent list. Specifically, firms with a relative trading volume $RelTradVol_{i,t}$ smaller than 0.4%, a bid-ask-spread $BidAskSpread_{i,t}$ larger than 20%[6], or trade discontinuities (i.e. zero returns) in 20% or more of the observations ($TradCont_{i,t}$ <80%) in the respective return time series are dropped.[7] To mimic the survivorship bias that is inherent to MSCI indices, small-cap stocks with a market capitalization $EquityMV_{i,t}$ <\$50 million are excluded. By setting this lower limit, firms that performed badly or became bankrupt are automatically dropped from the index. Similarly, corporations are excluded from MSCI indices when their market capitalization falls below a certain threshold. In addition, the sample only

[4]The minimum number of companies per index is one to maximize index history. The resulting index volatility is still comparable to equities and not biasing the results as robustness tests using a minimum of three and five companies demonstrate.

[5]Data availability on the country level is not sufficient to also construct subsector-specific indices.

[6]Both figures are calculated using 5-year averages of monthly data.

[7]The same cut-off values for relative trading volume, bid-ask-spreads, and trade discontinuities are used in section 5.3.3. Refer to section 4.4.3 for the definition of these variables.

includes firms if a full year of data is available, hence excluding the firm months after an initial public offering (IPO). Firms only enter the infrastructure index at the next annual rebalancing as it is the case for MSCI indices.

The above criteria for the index construction procedure reduce the cross-section from 1,458 to 824[8] infrastructure firms which is still three times as broad as the UBS Global Infrastructure index, the broadest publicly available infrastructure index.[9] Table 7.2 and Table 7.3 provide an overview of the number of infrastructure firms and their total market capitalization underlying the index calculations over time. The resulting index time series ranges from January 1973[10] till December 2009, i.e. covering 37 years, which is 2.5 times as long as the UBS index. The respective country-level history depends on the number of locally listed infrastructure firms in a particular country (and sector in case of sector indices) at that time. The second column in Table 7.4 provides an overview of the start dates of the respective country-specific infrastructure index time series. Nine developed countries are available from the start in 1973, amongst them Australia, Belgium, Canada, France, Germany, Hong Kong, Italy, Japan, U.S.. The first developing country, Malaysia, is added in 1986, followed by the Philippines (1987), the Republic of Korea (1988), and India (1989). The median annual real return for infrastructure is 6.5% with a variance of 32.0%, both are close to equity with 5.9% and 30.8%, respectively. The Breusch-Godfrey test indicates serial correlation for less than 5% of the countries at lag one. Homoscedasticity and stationarity can only be rejected for 7% and 2% of the cases at a 5% significance level, respectively. The median cross-correlation with U.S. infrastructure returns is 52%. These infrastructure return characteristics are

[8]The resulting sample contains 824 different firms, though not for all of them data are available in each year. Hence, the reported number of firms in Table 7.2 is strictly lower across all years.

[9]The UBS index is more restricted in its geographic (firms are mostly from developed countries; none from South America and Africa; few from emerging Asia), sector (no integrated telecom, cable, or satellite), and size scope (only large-caps).

[10]Earlier data are not available from TDS.

fairly similar to equity returns.

Table 7.2: Number of infrastructure firms by sector and time

	1973	1975	1985	1995	2005	2009
Infrastructure	34	113	173	380	638	749
Telecom	6	11	26	81	187	203
Satellite				4	14	18
Wireless	1	2	5	26	79	78
Fixed-line	5	8	17	38	75	79
Cable		1	4	13	19	28
Transport	6	9	14	41	111	135
Airports				5	14	20
Ports	1	1	1	9	24	31
Highways				4	32	34
Rail	4	6	10	16	24	29
Pipelines	1	2	3	7	17	21
Utilities	22	93	133	258	340	411
Electricity	18	49	55	129	178	240
Water		1	6	23	39	46
Gas	3	15	31	52	58	52
Multi	1	28	41	54	65	73

Source: Rödel and Rothballer (2012)

Table 7.3: Market capitalization of infrastructure firms by sector and time

	1973	1975	1985	1995	2005	2009
Infrastructure	16.0	36.9	218.5	1,145.1	3,239.3	3,840.1
Telecom	3.3	3.9	63.4	524.3	1,821.1	1,903.3
Satellite				4.2	49.7	42.5
Wireless	0.3	0.9	11.2	142.3	1,166.8	1,234.7
Fixed-line	3.0	2.9	50.5	364.7	531.2	539.2
Cable		0.2	1.7	13.1	73.4	86.9
Transport	2.0	3.1	22.8	90.1	277.6	370.2
Airports				3.9	16.0	25.3
Ports	0.1	0.1	0.2	3.9	18.5	31.0
Highways				1.9	67.9	67.8
Rail	1.2	2.7	21.3	75.8	133.1	183.8
Pipelines	0.7	0.4	1.4	4.6	42.0	62.3
Utilities	10.7	29.9	132.3	530.7	1,140.7	1,566.7
Electricity	9.1	18.2	76.6	355.3	647.4	954.9
Water		0.1	0.5	16.4	43.5	62.0
Gas	1.4	4.2	14.8	57.9	99.1	102.7
Multi	0.1	7.5	40.4	101.1	350.7	447.2

Note: Market capitalization in $ billion, as of the end of the respective year.
Source: Author

7.2.2 Inflation data

Inflation data are obtained from Global Financial Data (GFD) for all countries and the same time period from 1973 till 2009, as described in section 4.5.4. Figure 7.1 provides an overview of the inflation environments covered by the dataset. Until 1980, inflation above 5% was the norm, inflation beyond 10% wide-spread across 50% of the sample countries, and inflation beyond 15% still present. Afterwards, global inflation was gradually declining with 80% of the countries having less than 5% annual inflation in the late 1990s and throughout the 2000s. Since the dataset covers inflation environments of various levels, it is well suited to test inflation hedging.

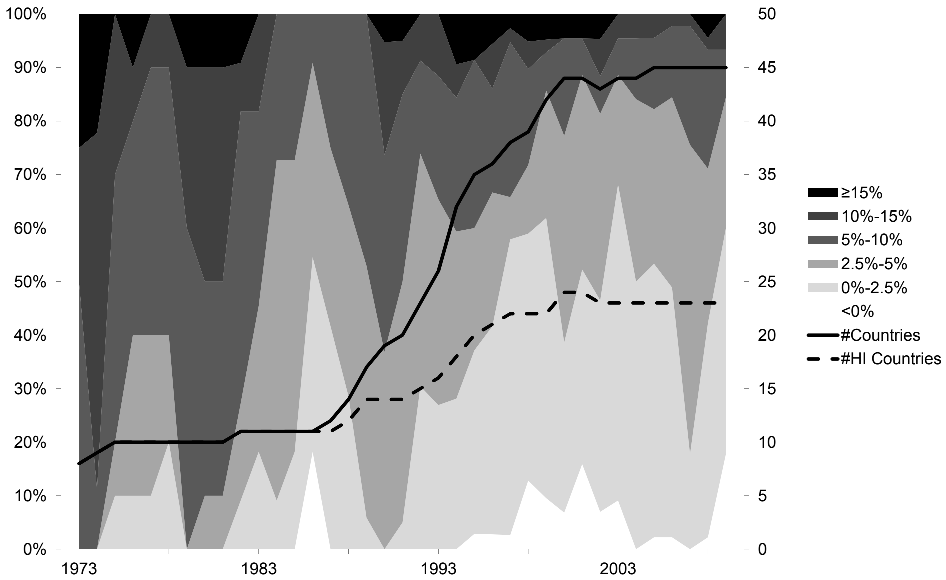
During the analysis period from 1973 to 2009, inflation stands at 5.4% on average with a standard deviation of 5.0%. Inflation exhibits slightly more autocorrelation and heteroscedasticity than returns (14% and 23% of the cases, respectively). It also shows a more persistent behavior than returns, but standard tests regarding the stationarity of inflation reveal conflicting evidence. While non-stationarity is rejected for the panel as a whole using the Im-Pesaran-Shin test[11], non-stationarity is rejected for 48% of the individual country series by the augmented Dickey-Fuller test. In contrast, the Kwiatkowski-Phillips-Schmidt-Shin test rejects stationarity in 65% of the countries (both at 10% significance; refer to Table 7.4 for details). These opposing results indicate fractional integration potentially biasing the coefficient estimates towards zero.

7.2.3 Regression model

The approach is inspired by the Fisher (1930) model, which proposes a linear one-for-one relation (i.e. $\beta^n = 1$) between expected inflation $E(\pi)$ and expected nominal

[11] Consistent non-stationary panel behavior can be rejected at a 0.1% significance level. The Im-Pesaran-Shin test corrects for auto- and cross-correlation in heterogeneous panels. The results are consistent for one and five year horizons.

Figure 7.1: Inflation data: Country coverage and inflation level



Notes: The solid black line represents the number of countries covered in the dataset (right axis). The dotted line shows the subset of developed economies that are covered. The shadings highlight the presence of inflation levels in the dataset (left axis), where a darker shading implies higher inflation rates. For example, data for eight countries are available for 1973 (all developed economies); 50% of these countries have an inflation between 5% and 10% and 25% report an inflation beyond 15%. Inflation is expressed as annual logarithmic returns. The Irish firms fall below index criteria in 2002 and are subsequently excluded from the analysis.
Source: Rödel and Rothballer (2012)

Table 7.4: Descriptive statistics: Inflation and infrastructure returns

Country	Start	Inflation							Infrastructure returns, real								Equity returns, real					
		μ	σ	ADF	KPSS	BPCW	BGF	Corr.	μ	σ	KPSS	BPCW	BGF	Corr.	#F	#FY	μ	σ	KPSS	BPCW	BGF	Corr.
Argentina	1992	5.7	8.4	0	6	11	46	32	3.5	47.9	4	83	17	65	9	103	7.5	34.9	4	56	93	37
Australia	1973	5.8	4.1	30	36	82	18	62	6.5	29.1	7	39	20	50	17	214	5.7	23.7	6	85	28	58
Austria	1988	2.2	1.0	5	15	88	49	43	7.2	23.1	5	41	55	51	5	69	5.0	32.0	6	80	50	53
Belgium	1973	3.8	3.1	35	36	0	58	70	6.9	19.0	8	66	95	56	7	103	5.4	23.2	11	11	66	73
Brazil	1993	21.3	56.3	0	14	12	0	9	4.5	37.6	3	70	23	18	34	314	11.3	40.0	3	1	7	24
Canada	1973	4.4	3.3	50	37	5	18	86	8.7	15.3	8	77	76	60	25	539	4.8	17.6	5	20	52	81
Chile	1989	6.6	6.0	47	33	85	13	44	13.3	30.0	19	56	47	29	12	218	11.8	25.7	12	76	1	38
China	1993	3.5	5.9	19	25	0	3	11	5.7	47.5	5	56	68	46	102	1039	-5.6	45.8	5	34	25	40
Czech Republic	1993	4.4	3.0	54	23	91	6	-12	6.5	32.8	10	94	37	34	2	60	7.5	28.7	13	7	87	23
Denmark	1993	2.1	0.5	0	6	84	26	66	10.0	31.4	8	96	92	66	3	40	7.7	27.0	5	34	68	62
Egypt	1998	7.1	5.0	33	4	94	37	30	21.1	96.0	7	73	84	44	4	37	16.1	58.3	12	12	5	52
Finland	1994	1.5	1.1	5	7	25	8	62	15.2	57.9	6	48	95	45	2	37	9.9	41.7	7	3	24	46
France	1973	4.6	4.1	68	47	0	7	72	7.5	37.1	9	85	79	62	18	129	5.7	26.4	8	4	48	55
Germany	1973	2.7	1.8	12	20	84	19	48	5.9	19.2	13	75	48	66	5	322	4.7	24.6	5	87	83	61
Greece	1996	3.2	0.7	0	6	76	22	59	0.1	36.1	7	34	11	77	7	67	4.5	49.1	8	32	71	56
Hong Kong	1973	5.4	5.3	29	15	1	60	63	9.8	38.1	7	38	100	62	34	398	7.2	40.1	6	90	69	64
Hungary	1997	5.7	2.5	2	16	63	72	8	-3.5	27.0	6	32	65	59	2	30	2.4	36.4	8	6	19	54
India	1989	7.5	3.9	3	22	15	27	36	8.9	46.6	9	50	58	30	30	190	9.9	37.4	6	35	51	52
Ireland	1999	4.9	1.1						-15.9	47.4						2	3.1	8.1				
Israel	1992	4.3	4.6	39	18	77	28	41	7.5	32.6	4	52	11	75	5	55	5.0	29.8	3	57	34	63
Italy	1973	7.2	6.0	37	30	1	40	77	5.6	30.7	10	21	64	54	31	481	2.1	29.7	10	89	9	54
Japan	1973	2.7	4.5	26	42	0	92	52	1.9	29.0	6	29	94	32	35	972	0.7	23.9	9	63	89	43
Korea, Republic Of	1988	4.3	2.0	16	14	21	44	13	16.9	50.9	4	1	58	19	4	53	2.4	35.8	3	93	5	15
Malaysia	1986	2.8	1.4	1	14	59	18	56	4.6	26.2	6	57	76	42	20	301	6.5	31.5	6	9	62	44
Mexico	1991	10.2	9.9	11	9	0	24	18	11.0	28.3	5	46	0	36	11	73	8.6	28.1	5	79	39	43
Morocco	2004	2.0	2.1						12.9	13.1					2	9	14.7	22.5				
Netherlands	1994	2.0	0.8	9	12	23	16	50	3.7	54.6	9	35	50	39	3	37	5.2	27.8	8	53	81	80
New Zealand	1991	2.2	1.0	2	7	61	53	66	7.7	22.8	4	19	78	48	7	112	6.6	18.1	5	5	89	50
Norway	1999	2.0	0.9	7	11	16	0	58	-4.3	62.7	11	34	28	70	1	10	5.0	40.1	8	1	34	45
Pakistan	1992	8.3	4.5	15	29	24	53	40	-2.4	44.2	8	33	36	2	5	90	3.5	54.0	6	73	16	30
Peru	1994	4.1	3.3	9	24	38	7	22	-3.8	53.8	3	51	0	-6	3	39	14.2	36.4	5	31	65	39
Philippines	1987	6.9	2.8	6	8	58	27	51	10.5	48.4	9	55	29	62	11	121	3.0	40.0	7	75	41	44
Poland	1998	3.6	2.8	41	19	31	82	11	-2.0	29.5	9	0	88	55	6	38	6.7	33.9	8	28	18	31
Portugal	1995	2.5	1.1	78	19	87	86	67	8.1	30.1	12	26	69	82	7	60	6.0	30.2	9	48	40	74
Russian Federation	1998	14.0	6.5	0	20	17	90	7	7.1	66.1	5	12	57	65	33	128	11.2	63.4	4	69	24	20
Saudi Arabia	2002	3.4	3.1	71	9	49	1	35	3.4	50.5	12	26	7	32	4	16	9.2	61.7	8	38	18	38
Singapore	1993	1.3	1.6	2	11	52	33	58	1.2	28.9	5	84	97	64	5	55	2.5	33.6	3	84	45	62
South Africa	1996	5.9	3.2	0	7	52	11	51	18.9	46.2	6	44	67	53	2	20	7.2	22.8	6	39	39	27
Spain	1987	3.7	1.6	67	23	42	39	64	10.7	25.4	5	80	77	78	13	216	7.2	24.9	10	77	28	42
Sweden	1988	2.4	2.7	23	28	0	13	67	6.4	24.9	8	52	68	74	3	45	8.7	29.7	6	50	97	58
Switzerland	1974	2.1	1.8	1	12	35	45	53	5.4	21.0	11	85	35	33	9	152	6.9	21.3	5	76	74	78
Taiwan	1991	1.6	1.7	6	20	32	50	37	-6.9	22.6	7	39	44	13	8	76	4.9	37.0	3	34	3	52
Thailand	1990	2.6	4.7	0	5	1	29	55	9.7	56.0	10	55	63	22	14	156	2.3	43.5	10	31	65	15
Turkey	1993	33.8	25.9	76	11	29	2	20	-1.4	87.5	6	1	14	39	7	55	2.9	61.8	3	50	25	44
United Kingdom	1981	3.1	1.8	0	25	0	28	75	10.5	23.9	5	17	14	75	21	437	8.5	16.5	3	18	28	70
United States	1973	4.3	3.0	15	23	19	0	100	6.1	18.1	8	7	29	100	161	4864	5.6	18.6	12	33	22	100
Median	1992	3.9	3.0	12	17	30	27	51	6.5	32.0	7	47	57	52	7	83	5.9	30.8	6	39	40	51

Note: All data in per cent. Inflation and domestic infrastructure data relates to the same time frame, calculated on annual logarithmic returns. '73 - '09 mean and average relevant for international comparisons.

Abbreviations: Start: Inception year of all series (end for all 2009); μ: annualized logarithmic, arithmetic mean return since start year; σ: respective standard deviation; ADF_p: Augmented Dickey-Fuller p-value; PP_p: Phillips-Perron p-value; $KPSS_t$ Kwiatkowski-Phillips-Schmidt-Shin t-value with 0.119 (0.146) for significance level of 10% (5%); Hettest: Breusch-Pagan/ Cook-Weisberg p-value; BGF_i: Breusch-Godfrey p-value at lag i; Corr.: Correlation coefficient to respective time series of the United States of America.
Source: Rödel and Rothballer (2012)

returns $E(R^n)$:[12]

$$E(R^n) = \alpha + \beta^n E(\pi) + \epsilon \tag{7.1}$$

While Fisher's ex-ante model is meaningful for fixed-income returns to maturity, long-term equity returns are rather determined as a result of inflation, motivating a shift to an ex-post model. Following the approach of Kaserer and Rödel (2011), further variables in addition to the constant for real return and the regressor for absolute inflation are introduced. $\Delta\pi$[13] accounts for changes in inflation expectations or inflation volatility, and the real GDP growth ΔGDP eliminates potential biases arising from the fact that lower economic growth during inflationary periods causes lower returns. Moreover, country dummies D_c allow differences in average returns arising from institutional or market differences. Regressing on real returns R^r alters the null hypothesis for a perfect inflation hedge to $\beta^r = 0$ (corresponding to $\beta^n = 1$) without affecting the other parameter estimates. For a panel dataset with C countries and T years, the regression equation is written as

$$R^r_{c,t} = R^n_{c,t} - \pi_{c,t} = \alpha_c + \beta^r \pi_{c,t} + \gamma \Delta\pi_{c,t} + \delta \Delta GDP_{c,t} + \epsilon_{c,t} \tag{7.2}$$
$$with\ c = 1, ..., C,\ \ t = 1, ..., T.$$

where $R^r_{c,t}$ ($R^n_{c,t}$) denotes the realized real (nominal) return in country c for time period t, β^r the inflation beta (with respect to real returns), $\pi_{c,t}$ the realized inflation, $\Delta\pi_{c,t}$ the change in inflation expectations (proxied by the inflation change over the period), $\Delta GDP_{c,t}$ the real GDP growth, and α_c a country-specific return dummy.

To analyze both the short-term and the long-term hedging behavior a one year as well as for a five year investment horizon is used. While for the short-term horizon the t refers to a given year of data, it refers to a rolling five year period

[12] Both returns and inflation are expressed in continuous compounding, i.e. the natural logarithm of the respective figure.

[13] Proxied by the difference of the inflation at the start and at the end of the investment horizon.

for the long-term horizon (i.e. t_1 contains data from 1973 to 1977, t_2 contains data from 1974 to 1978, ...). Because of these five year rolling averages, the severe auto-correlation arising from the overlapping observations needs to be corrected by applying the matrix transformation proposed by Britten-Jones et al. (2011). Equation (7.2) then transforms into

$$\begin{aligned} \vec{R_c^r} &= \hat{X}_{k,c}\vec{b_k^r} + \vec{\epsilon_c} \ with \\ \hat{X}_{k,c} &= A_k' X_{k,c}(X_{k,c}' A_k A_k' X_{k,c})^{-1} X_{k,c}' X_{k,c}, \\ c &= 1, ..., C \end{aligned} \tag{7.3}$$

with $\vec{R_c^r}$ denoting the $T \times 1$ vector of annual real returns of an asset, $\hat{X}_{k,c}$ the transformed $T \times l$ regressor matrix, $X_{k,c}$ the $(T - k) + 1 \times l$ regressor matrix with the overlapping multi-period observations of all l regresssors (α_c, $\pi_{c,t}$, $\Delta\pi_{c,t}$, and $\Delta GDP_{c,t}$), A_k the $(T - k) + 1 \times T$ matrix to compute overlaps with entries $a_{i,j} = 1 \ if \ i \leq j \leq i + k - 1$ and 0 otherwise, and $\vec{b_k^r}$ the $l \times 1$ coefficient vector, and k the investment horizon. Equation (7.3) is fitted to the panel dataset using spatial correlation consistent standard errors according to Driscoll and Kraay (1998) to account for the heteroscedasticity as well as the simultaneous and lagged cross-correlation in the data.

The empirical analysis primarily focuses on the inflation coefficient β^r which is estimated as part of $\vec{b_k^r}$ for each asset based on regression equation (7.3). If it is statistically insignificant and/or close to zero, the asset's real returns are unaffected by the level of inflation and thus serves as a hedge against the inflation level. If the coefficient γ on $\Delta\pi_{c,t}$ is statistically insignificant and/or close to zero, the asset proves robust against inflation expectations or inflation volatility.

In addition to the absolute inflation hedging characteristic of infrastructure, the relative performance in comparison to equity is of interest. Therefore, a dummy variable is introduced into the original model for each regressor. The dummy equals 0 for equity and 1 for infrastructure. The resulting extended equation is then estimated with the data of both equity and infrastructure. The estimated coefficients for the primary variables inflation, change of inflation, and GDP growth remain identical, but the dummies' values and signs indicate the relative inflation hedging performance of infrastructure relative to equities, and the p-value indicates whether the performance difference is statistically significant or not. The results reported in the next section in Table 7.5 include the inflation coefficients obtained from the original regression (columns labeled "Coef.") and the difference coefficients obtained from the extended regression with dummies (columns labeled 'Δ'Coef."). Though the regression approach corrects for the severe auto-correlation of overlapping data, the estimates for inflation might still be biased towards zero. As the analysis primarily focuses on the coefficient difference between equity and infrastructure and as both coefficients suffer from the same bias, the bias in the difference is less severe.

To provide a fair comparison between equities and infrastructure, any sample biases are eliminated by aligning the number of observations used in each regression. Hence, observations are only included if they are available for all time series under investigation. As a result, the time series of infrastructure and equity always contains the same number of observations in any peculiar analysis.

7.3 Empirical results

7.3.1 Domestic infrastructure

This section presents the empirical findings on the relative inflation hedging characteristics of infrastructure and equities. After investigating domestic infrastructure, portfolios clustered by sector and pricing power are analyzed.

The upper part of Table 7.5 provides the empirical results for the comparison of domestic infrastructure with domestic equity at the one and five year investment horizon. On the one year horizon, the inflation coefficient of infrastructure is slightly less negative (-1.69), than the inflation coefficient for equity (-2.04). However, the coefficient difference of 0.35 is not statistically significant. Both domestic equity and infrastructure turn out as bad inflation hedges, since a 1%-point higher level of inflation implies a reduction of real returns of 1.69%-points and 2.04%-

points, respectively. A good inflation hedge would not show any change of real return. Similarly, the analysis for the five year investment horizon produces a lower inflation coefficient for infrastructure relative to equities (-0.58 vs. -0.67). In this long-term comparison both assets again appear as not particularly good inflation hedges, however both coefficients are not statistically significant different from 0. Hitherto, the inflation hedging properties of both assets are better on the five year horizon than on the one year investment horizon. Yet, the hypothesis that infrastructure constitutes an enhanced inflation hedge cannot be verified, since the difference coefficient of 0.10 is again insignificant (and even smaller than in the short-term comparison). At the same time, infrastructure reacts more sensitive to changes in inflation for long horizons (-0.45 vs. -0.16), while there is no noticeable difference for the one year horizon (-0.22 vs. -0.21). The worse performance for the five year horizon implies that infrastructure is less resilient than equities to unexpected inflation shocks. To sum up, the empirical results from the analysis of domestic infrastructure and equity returns do not support hypothesis H3.1. Note, that this analysis mostly covers data for low and medium inflation environments of less than 21% p.a., since the available infrastructure data time series mostly cover the 1990s and 2000s. As pointed out by Kaserer and Rödel (2011), real equity returns typically show negative inflation coefficients in such a low and medium inflation environment in contrast to their neutral behavior during high inflations of above 21% per annum. This implies that due to the similarities in inflation hedging between equities and infrastructure, infrastructure may also constitute a good inflation hedge during periods characterized by high inflation rates. Yet, it is not possible to analyze the behavior of infrastructure under such circumstances based on this dataset.

7.3.2 Domestic infrastructure by sector

To provide a more refined view of individual infrastructure sectors, the infrastructure sample is split into telecommunication, transportation, and utilities subsamples. Due to this disaggregated approach, the number of observations is reduced

Table 7.5: Regression results: Inflation betas of equities and infrastructure

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Infrastructure vs. equity										
Infrastructure	1	918	-1.69	0.02	0.35	0.34	-0.22	0.40	-0.01	0.92
Equity	1	918	-2.04	0.00			-0.21	0.34		
Infrastructure	5	927	-0.58	0.42	0.10	0.76	-0.45	0.24	-0.29	0.05
Equity	5	927	-0.67	0.28			-0.16	0.70		
Infrastructure sectors vs. infrastructure/ equity										
Infrastructure	1	617	-1.96	0.01	0.34	0.42	-0.11	0.53	0.02	0.76
Telecom	1	617	-1.81	0.04	0.49	0.38	-0.10	0.53	0.02	0.77
Transport	1	392	-2.09	0.01	0.39	0.45	0.11	0.85	0.64	0.26
Utilities	1	617	-2.05	0.00	0.25	0.52	-0.11	0.52	0.01	0.89
Equity	1	617	-2.30	0.00			-0.12	0.44		
Infrastructure	5	600	-0.60	0.38	0.06	0.88	-0.26	0.42	-0.10	0.47
Telecom	5	600	-0.46	0.58	0.21	0.73	-0.48	0.18	-0.32	0.07
Transport	5	371	-1.14	0.08	-0.21	0.65	2.05	0.26	1.81	0.21
Utilities	5	600	-0.64	0.24	0.02	0.96	-0.02	0.94	0.14	0.54
Equity	5	600	-0.67	0.25			-0.16	0.63		
Static pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	655	-1.90	0.01	0.27	0.48	-0.14	0.49	0.00	0.95
High PP infra.	1	655	-1.82	0.01	0.35	0.36	-0.16	0.45	-0.02	0.81
Low PP infra.	1	655	-1.96	0.01	0.21	0.59	-0.16	0.45	-0.02	0.73
Equity	1	655	-2.17	0.00			-0.14	0.45		
Infrastructure	5	641	-0.36	0.62	0.09	0.80	-0.36	0.28	-0.20	0.16
High PP infra.	5	641	-0.16	0.82	0.29	0.42	-0.38	0.23	-0.23	0.30
Low PP infra.	5	641	-0.37	0.59	0.07	0.83	-0.36	0.26	-0.20	0.24
Equity	5	641	-0.45	0.46			-0.16	0.66		
Dynamic pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	557	-2.30	0.01	0.27	0.37	-0.17	0.41	-0.01	0.87
High PP infra.	1	557	-2.11	0.01	0.46	0.27	-0.20	0.36	-0.04	0.61
Low PP infra.	1	557	-2.29	0.02	0.28	0.53	-0.17	0.40	-0.01	0.83
Equity	1	557	-2.57	0.01			-0.16	0.37		
Infrastructure	5	527	-0.43	0.57	0.13	0.64	-0.32	0.31	-0.24	0.11
High PP infra.	5	527	-0.05	0.95	0.52	0.23	-0.33	0.29	-0.25	0.27
Low PP infra.	5	527	-0.66	0.41	-0.10	0.78	-0.28	0.34	-0.20	0.23
Equity	5	527	-0.56	0.39			-0.08	0.82		

This table compares the inflation hedging characteristics of various domestic infrastructure indices with domestic equity indices across 46 countries (based on real returns) at the one and five year investment horizon. The column 'Coef.' ('ΔCoef.') reports the coefficient estimate based on the original (extended) regression, 'p-Val.' the respective significance level.

Notes: For simplicity, the ΔGDP coefficients are not reported. A narrower anchor is applied for transportation and dilutes its result's comparability. Observations that exhibit high leverage with annual inflation beyond 21% are excluded from the regression. R^2 ranges between 4 and 9%. Multicollinearity is of limited concern with all variance inflation factors $\sqrt{VIF} < 3$.

Abbreviations: k: Investment horizon; N: Number of observations; PP: Pricing power.

Source: Rödel and Rothballer (2012)

from 918 for the total infrastructure sample to 617 for the telecom and utilities subsamples on the one-year horizon. As the data availability of the transportation sector is even further constrained (N=392), the analysis only focuses on the earlier two sectors. Both telecommunication (-1.81) and utilities (-2.05) perform slightly better than equities with respect to the inflation level, and similarly with regard to changes of inflation on the one year investment horizon. Again, the relative advantage to equities shrinks for both sectors when analyzing the five year horizon. However, the differences between both sectors and equities are insignificant, leading to the conclusion that they exhibit fairly similar inflation hedging characteristics as equities. Again, the coefficients for all assets are significantly negative for the one year horizon, and insignificantly negative for the five year horizon reflecting the overall relatively bad inflation hedging in these inflation environments. In line with the previous aggregate analysis, the sector-specific analysis presents no statistically significant support for hypothesis H3.1 that infrastructure is an enhanced inflation hedge. Yet, the sector-specific results confirm the earlier aggregate analysis for a smaller sample size, and thus provide a useful robustness test across time.

7.3.3 Domestic infrastructure by pricing power

As overall infrastructure seems not to be a superior inflation hedge relative to equities, this section explores whether infrastructure with particularly high pricing power outperforms infrastructure with low pricing power infrastructure and equities. In order to separate the sample of listed infrastructure into subgroups of high and low pricing power two different approaches are pursued. First, the sample is split based on a simple, static classification of relative pricing power on the subsector level. In a second step, the clustering is refined using subsector-, country- and time-specific competition data (as pricing power proxies) from OECD (2007).

The static classification is based on an evaluation of the intra- and inter-sectoral competitiveness of each subsector. For example, airports face medium competition from other airports as catchment areas often overlap and transfer passengers can choose between airports. In contrast, highways only face limited direct competition from regional roads. However, both airports and highways face medium inter-modal (or inter-sectoral) competition from e.g. rail. The second and third columns in Table 7.6 provide a summary of these assessments for all subsectors. Subsectors with at least significant intra-sectoral competition or with at least medium intra- and inter-sectoral competition are assigned to the low pricing power (high competitiveness) cluster, as indicated in the last column of the table. To verify the pricing power classification resulting from the intra- and inter-sectoral competitiveness evaluation, the network structure characteristic of each subsector is assessed. The underlying logic is that node-like infrastructure assets can be more cheaply replicated than edges. Hence, node-like infrastructure sectors have lower entry barriers, higher competitiveness, and less pricing power. For example, consider the case of telecommunication. Competitiveness in edge-like fixed-line networks, which are costly to install and cannot be duplicated in an economically viable way, is more limited than in wireless where node-like base stations can be easily replicated. The fourth column of Table 7.6 contains the network type assessment for all subsectors. As shown in the last column in Table 7.6, both the competition and the network structure based classification approaches yield the same pricing power clustering. Note, that the classification of each subsector does neither vary across countries nor time.

In a next step the static classification is refined in order to account for the heterogeneity in pricing power (and competitiveness) that unfolds across countries and time. For this purpose, the $MarketCompetition_{i,t}$ variable, as introduced in section 4.5.2, is employed. This variable is based on a structured questionnaire on the entry barriers, the market structure, and the vertical integration in key infrastructure sectors in all OECD countries from 1975 to 2007 (OECD (2007)). It includes data on electricity, gas, rail as well as fixed-line and wireless communication covering the majority of the sample firms. For each subsector-country-year combination an indicator between 0 and 6 is assigned, where 0 refers to a competitive market (with low pricing power) and 6 describes a regulated market (with high pricing power). 3 is used as an equidistant cut-off point to cluster subsectors

Table 7.6: Static pricing power classification of infrastructure subsectors

Subsector	Intra-sectoral competition	Inter-sectoral competition	Network type	Pricing power cluster
Telecommunication				
Satellite	Significant: satellites with same coverage	Medium: (sea) cable	Node	Low
Wireless	Significant: wireless networks with same coverage	Medium: fixed-line	Node	Low
Fixed-line	Limited: usually only in long-distance	Medium: wireless	Edge	High
Cable	Limited: usually regional monopoly	Medium: satellite, antenna	Edge	High
Transport				
Airports	Medium: airports in same catchment; transfer passenger	Medium: rail, highways	Node	Low
Ports	Medium: ports serving same hinterland	Medium: rail, highways, pipelines	Node	Low
Highways	Limited: only from regional roads	Medium: rail, water & air transport, pipelines	Edge	High
Railroads	Limited: only few parallel tracks	Medium: highways, water & air transport, pipelines	Edge	High
Pipelines	Limited: usually little redundancy	Medium: rail, water transport	Edge	High
Utilities				
Electricity	Medium: different generation technologies	Medium: other energy sources (e.g. oil)	Node	Low
Water	Limited: usually regional monopoly	None: no substitute	Edge	High
Gas	Limited: usually regional monopoly	Limited: Truck supply; other heating commodities	Edge	High
Multi	Limited: same as electricity, gas, water	Limited: same as electricity, gas, water	Edge	High

Note: Subsectors with at least significant intra-sectoral competition or with at least medium intra- and inter-sectoral competition are assigned to the low pricing power (high competitiveness) cluster.
Source: Rödel and Rothballer (2012)

as either high or low pricing power for a given year and country. For sectors that are not covered and for non-OECD countries the pricing power assignment from the previously introduced static clustering is kept in order to maintain a sufficient number of observations. For the years 1973 and 1974, the corresponding 1975 values are used. This assumption is not critical since tight regulation was pervasive in the 1970s across all countries with most indicators standing at 6. Similarly, for any years after 2007, namely 2008 and 2009, the respective 2007 value is used. Again this of limited concern since deregulation progressed monotonously.

The lower part of Table 7.5 contains the empirical results for the static and dynamic pricing power classification. In the static approach, the inflation betas of high pricing power infrastructure portfolios (-1.82 and -0.16) are consistently larger on the one and the five year horizon than for equities (-2.17 and -0.45) and low pricing power infrastructure (-1.96 and -0.37). However, none of the coefficient differences are significant. In the dynamic approach the enhanced inflation hedging features of high pricing power infrastructure become more pronounced. On the one year horizon, the difference coefficient for high pricing power infrastructure is 0.46 and for the five year horizon it is 0.52. Though both difference coefficients are insignificant, the level of significance (27% and 23%-level, respectively) is the strongest in the analysis. More importantly, while equity has an inflation coefficient of -0.56 and low pricing power infrastructure of -0.66 on the five year horizon, high pricing power infrastructure hedges inflation almost perfectly with a coefficient of -0.05, being close to zero. Hence, infrastructure with high pricing power seem to provide a more robust hedge against inflation than infrastructure with low pricing power and equity as inflation has no material effect on its real returns. For these specific assets characterized by considerable entry barriers, vertical integration, and high market shares, hypothesis H3.1 indeed holds, though with weak statistical significance and only for the five year investment horizon. Similar to the above results, infrastructure is more sensitive to unexpected inflation or inflation volatility. It seems that high pricing power only be capitalized on in stable inflation environments.

7.3.4 Robustness

The robustness of the above analysis is tested with regard to methodology (no transformation), potential misspecification (excluding GDP growth and Δinflation), and data subsamples (excluding low-income countries). The results for the regression without the Britten-Jones et al. (2011) transformation are provided in Table 7.7, the results with inflation as the only coefficient in Table 7.8, and the results for high income countries only in Table 7.9. None of the robustness checks gives an indication that infrastructure assets are generally superior to equities, contradicting H3.1. Even in the regression without the Britten-Jones et al. (2011) transformation, i.e. when the p-values of the five year investment horizon are overstated, the inflation coefficient differences of infrastructure are still insignificant. The results for high-income countries only are also highly consistent with the original regression. When excluding the additional explanatory variables for the change of inflation and GDP, the inflation coefficient on the five year horizon generally gets closer to zero for equities and infrastructure, but the difference is statistically still indistinguishable. The robustness tests also confirm the finding that high pricing power infrastructure provides an enhanced inflation hedge. In the regression without the Britten-Jones et al. (2011) transformation, the difference coefficient of 0.52 becomes significant on the 5% level. Moreover, in the specifications without Δinflation and when focusing on high-income countries, high pricing power infrastructure even shows a positive inflation coefficient of 0.55 and 0.14 for the five year horizon, respectively (Table 7.8 and Table 7.9). The difference coefficients of 0.60 and 0.83 are close to being significant and show the significant outperformance relative to equities.

7.4 Discussion

7.4.1 Reasons for limited inflation hedging

The empirical results in the previous section suggest that listed infrastructure in general is not a superior inflation hedge in comparison to average equities, con-

Table 7.7: Robustness test: Regression results without transformation

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Infrastructure vs. equity										
Infrastructure	1	918	-1.69	0.02	0.35	0.34	-0.22	0.40	-0.01	0.92
Equity	1	918	-2.04	0.00			-0.21	0.34		
Infrastructure	5	745	-0.58	0.15	0.10	0.47	-0.45	0.09	-0.29	0.06
Equity	5	745	-0.67	0.06			-0.16	0.39		
Infrastructure sectors vs. infrastructure/ equity										
Infrastructure	1	617	-1.96	0.01	0.34	0.42	-0.11	0.53	0.02	0.76
Telecom	1	617	-1.81	0.04	0.49	0.38	-0.10	0.53	0.02	0.77
Transport	1	392	-2.09	0.01	0.39	0.45	0.11	0.85	0.64	0.26
Utilities	1	617	-2.05	0.00	0.25	0.52	-0.11	0.52	0.01	0.89
Equity	1	617	-2.30	0.00			-0.12	0.44		
Infrastructure	5	440	-0.60	0.14	0.06	0.80	-0.26	0.17	-0.10	0.46
Telecom	5	440	-0.46	0.36	0.21	0.47	-0.48	0.05	-0.32	0.09
Transport	5	263	-1.14	0.06	-0.21	0.38	2.05	0.19	1.81	0.02
Utilities	5	440	-0.64	0.07	0.02	0.93	-0.02	0.90	0.14	0.31
Equity	5	440	-0.67	0.04			-0.16	0.17		
Static pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	655	-1.90	0.01	0.27	0.48	-0.14	0.49	0.00	0.95
High PP infra.	1	655	-1.82	0.01	0.35	0.36	-0.16	0.45	-0.02	0.81
Low PP infra.	1	655	-1.96	0.01	0.21	0.59	-0.16	0.45	-0.02	0.73
Equity	1	655	-2.17	0.00			-0.14	0.45		
Infrastructure	5	485	-0.36	0.38	0.09	0.66	-0.36	0.09	-0.20	0.15
High PP infra.	5	485	-0.16	0.74	0.29	0.21	-0.38	0.10	-0.23	0.19
Low PP infra.	5	485	-0.37	0.33	0.07	0.73	-0.36	0.13	-0.20	0.23
Equity	5	485	-0.45	0.21			-0.16	0.24		
Dynamic pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	557	-2.30	0.01	0.27	0.37	-0.17	0.41	-0.01	0.87
High PP infra.	1	557	-2.11	0.01	0.46	0.27	-0.20	0.36	-0.04	0.61
Low PP infra.	1	557	-2.29	0.02	0.28	0.53	-0.17	0.40	-0.01	0.83
Equity	1	557	-2.57	0.01			-0.16	0.37		
Infrastructure	5	391	-0.43	0.28	0.13	0.48	-0.32	0.05	-0.24	0.17
High PP infra.	5	391	-0.05	0.92	0.52	0.05	-0.33	0.08	-0.25	0.22
Low PP infra.	5	391	-0.66	0.09	-0.10	0.70	-0.28	0.07	-0.20	0.23
Equity	5	391	-0.56	0.14			-0.08	0.42		

This table resembles Table 7.5, but solely relies on Driscoll and Kraay (1998) standard errors to correct for auto-correlation induced by the overlapping data, not the transformation of Britten-Jones et al. (2011). Consequently, only the p-values of the five year investment horizon are overstated. The column 'Coef.' ('ΔCoef.') reports the coefficient estimate based on the original (extended) regression, and 'p-Val.' the respective significance level.
Notes: For simplicity, the ΔGDP coefficients are not reported. A narrower anchor is applied for transportation and dilutes its result's comparability. Multi-collinearity is of limited concern with all variance inflation factors $\sqrt{VIF} < 3$.
Abbreviations: k: Investment horizon; N: Number of observations; PP: Pricing power.
Source: Rödel and Rothballer (2012)

Table 7.8: Robustness test: Regression results with inflation as only regressor

Series	k	N	Inflation			
			Coef.	p-Val.	ΔCoef.	p-Val.
Infrastructure vs. equity						
Infrastructure	1	917	-1.58	0.03	0.44	0.24
Equity	1	917	-2.01	0.00		
Infrastructure	5	927	-0.36	0.63	0.14	0.68
Equity	5	927	-0.50	0.42		
Infrastructure sectors vs. infrastructure/ equity						
Infrastructure	1	616	-1.68	0.02	0.48	0.26
Telecom	1	616	-1.47	0.08	0.69	0.21
Transport	1	392	-2.12	0.01	0.49	0.33
Utilities	1	616	-1.85	0.00	0.31	0.40
Equity	1	616	-2.15	0.01		
Infrastructure	5	600	-0.04	0.96	0.15	0.74
Telecom	5	600	0.14	0.89	0.33	0.63
Transport	5	371	-0.86	0.17	-0.35	0.47
Utilities	5	600	-0.27	0.65	-0.07	0.87
Equity	5	600	-0.19	0.75		
Static pricing power infrastructure portfolios vs. infrastructure/ equity						
Infrastructure	1	654	-1.63	0.02	0.40	0.30
High PP infra.	1	654	-1.65	0.01	0.39	0.32
Low PP infra.	1	654	-1.65	0.02	0.39	0.32
Equity	1	654	-2.02	0.01		
Infrastructure	5	641	0.02	0.98	0.19	0.63
High PP infra.	5	641	0.19	0.81	0.36	0.36
Low PP infra.	5	641	0.01	0.99	0.18	0.63
Equity	5	641	-0.17	0.78		
Dynamic pricing power infrastructure portfolios vs. infrastructure/ equity						
Infrastructure	1	556	-1.93	0.02	0.46	0.11
High PP infra.	1	556	-1.94	0.01	0.45	0.26
Low PP infra.	1	556	-1.90	0.03	0.48	0.25
Equity	1	556	-2.38	0.01		
Infrastructure	5	527	0.12	0.88	0.17	0.60
High PP infra.	5	527	0.55	0.46	0.60	0.15
Low PP infra.	5	527	-0.08	0.92	-0.04	0.93
Equity	5	527	-0.05	0.94		

This table resembles Table 7.5, but ignores the independent variables $\Delta\pi$ and ΔGDP (as test for potential misspecification). The column 'Coef.' ('ΔCoef.') reports the coefficient estimate based on the original (extended) regression, and 'p-Val.' the respective significance level.
Notes: A narrower anchor is applied for transportation and dilutes its result's comparability.
Abbreviations: k: Investment horizon; N: Number of observations; PP: Pricing power.
Source: Rödel and Rothballer (2011)

Table 7.9: Robustness test: Regression results for high income countries

Series	k	N	Inflation				ΔInflation			
			Coef.	p-Val.	ΔCoef.	p-Val.	Coef.	p-Val.	ΔCoef.	p-Val.
Infrastructure vs. equity										
Infrastructure	1	592	-1.15	0.07	0.16	0.73	-2.33	0.01	-1.05	0.08
Equity	1	592	-1.31	0.09			-1.28	0.09		
Infrastructure	5	593	-0.49	0.50	0.08	0.86	-4.34	0.02	-1.29	0.16
Equity	5	593	-0.57	0.36			-3.05	0.13		
Infrastructure sectors vs. infrastructure/ equity										
Infrastructure	1	362	-1.52	0.03	0.17	0.79	-1.63	0.11	-1.05	0.13
Telecom	1	362	-1.51	0.08	0.17	0.82	-1.62	0.16	-1.04	0.32
Transport	1	281	-1.28	0.12	0.32	0.57	1.44	0.49	1.39	0.06
Utilities	1	362	-1.50	0.01	0.18	0.75	-1.40	0.21	-0.82	0.13
Equity	1	362	-1.68	0.08			-0.58	0.57		
Infrastructure	5	351	-0.72	0.35	0.14	0.80	-4.52	0.02	-2.05	0.06
Telecom	5	351	-0.56	0.59	0.29	0.71	-6.42	0.01	-3.95	0.01
Transport	5	271	-0.81	0.21	0.02	0.96	-0.42	0.84	2.15	0.09
Utilities	5	351	-0.59	0.23	0.26	0.63	-4.30	0.03	-1.84	0.05
Equity	5	351	-0.85	0.25			-2.46	0.31		
Static pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	419	-1.27	0.05	0.11	0.83	-1.99	0.03	-0.90	0.14
High PP infra.	1	419	-1.19	0.15	0.20	0.74	-1.93	0.09	-0.84	0.38
Low PP infra.	1	419	-1.50	0.02	-0.11	0.81	-2.55	0.01	-1.46	0.00
Equity	1	419	-1.39	0.11			-1.10	0.17		
Infrastructure	5	413	-0.43	0.56	0.00	0.99	-3.91	0.03	-1.20	0.23
High PP infra.	5	413	-0.01	0.99	0.42	0.46	-3.49	0.06	-0.79	0.59
Low PP infra.	5	413	-0.46	0.50	-0.03	0.94	-4.31	0.04	-1.60	0.07
Equity	5	413	-0.43	0.49			-2.70	0.19		
Dynamic pricing power infrastructure portfolios vs. infrastructure/ equity										
Infrastructure	1	339	-1.61	0.05	0.34	0.47	-2.60	0.03	-1.50	0.01
High PP infra.	1	339	-1.44	0.15	0.51	0.48	-2.66	0.03	-1.56	0.12
Low PP infra.	1	339	-1.91	0.03	0.04	0.95	-2.47	0.07	-1.37	0.02
Equity	1	339	-1.95	0.04			-1.09	0.31		
Infrastructure	5	325	-0.56	0.56	0.12	0.78	-4.13	0.07	-2.79	0.00
High PP infra.	5	325	0.14	0.87	0.83	0.26	-3.60	0.10	-2.25	0.16
Low PP infra.	5	325	-0.92	0.39	-0.23	0.71	-3.19	0.21	-1.84	0.13
Equity	5	325	-0.68	0.37			-1.35	0.50		

This table resembles Table 7.5, but only includes the observations of the high income countries as part of the MSCI World (as test for regression stability). The column 'Coef.' ('ΔCoef.') reports the coefficient estimate based on the original (extended) regression, and 'p-Val.' the respective significance level.
Notes: For simplicity, the ΔGDP coefficients are not reported. A narrower anchor is applied for transportation and dilutes its result's comparability. Multi-collinearity is of limited concern with all variance inflation factors $\sqrt{VIF} < 3$.
Abbreviations: k: Investment horizon; N: Number of observations; PP: Pricing power.
Source: Rödel and Rothballer (2012)

tradicting the common investors' claim and the initial hypothesis H3.1. Domestic infrastructure hedges inflation just as good (or bad) as domestic equity, as the difference between listed infrastructure and equities is mostly negligible and statistically not significant. Similarly, none of the analyzed infrastructure sectors telecommunication, transport, and utilities appears to be an enhanced inflation hedge relative to equities. Only portfolios of infrastructure firms with particularly strong pricing power – proxied by OECD data on the entry barriers, the market structure, and vertical integration in infrastructure markets – give an indication that select infrastructure assets may provide inflation-linked returns for long investment horizons. Though the inflation beta for these latter assets is close to zero, i.e. real returns are not sensitive to inflation, the coefficient difference versus equities is insignificant and high pricing power infrastructure also fails to hedge inflation on an annual horizon. These findings are in contrast to the widely believed investment hypotheses that infrastructure in general is a good inflation hedge due to its monopolistic pricing power, the prevailing regulatory regimes, and the low variable cost exposure. There seem to be several inverse effects at play that neutralize these arguments.

First, the pricing power of infrastructure firms is probably more restricted than often assumed. Effective regulation prescribing prices, quality, and investments is in place across most countries – particularly developed countries which make up the largest part of the analyzed sample – and is increasingly enforced by independent and sophisticated regulatory authorities. Moreover, the deregulation policies over the past 30 years have lowered the entry barriers, have unbundled previously vertically integrated firms, and have instituted new competition through third-party network access pricing rules across most infrastructure sectors. Consequently, the competitiveness of infrastructure industries has increased, as reflected in the aggregate OECD ETCR indicator which fell from about 5 to 2.5 (measured on a scale between 6 and 0) between 1975 and 2003 (Conway and Nicoletti (2006)). These developments may have reduced the average pricing power in the infrastructure sample (or alternatively, the relative share of high pricing power infrastructure firms) and thus causing the unexpectedly bad inflation hedging qualities in the overall sample.

While certain incentive regimes, such as RPI-X regulation, are often argued to be one of the main reasons for the supposedly good inflation hedging properties of infrastructure, the variety of regulatory regimes that are actually employed in practice does not allow such a general conclusion. The survey of Égert (2009) shows that in late 2007 cost-based regulatory regimes such as rate-of-return are still widely used across most infrastructure sectors in OECD countries, despite the general trend towards incentive regulation. For example, in electricity transmission 16 countries use cost-based regulation, while only seven countries apply incentive regulation. Cost-based regimes do not necessarily protect against inflation if the regulated asset base is determined based on historic prices and if regulatory lags are long. But also for firms under incentive regulation a correlation between returns and CPI is not granted. On the one hand, there may be a mismatch between the firms' cost base and the CPI goods basket. On the other hand, if prices are determined using specific inflation measures such as construction costs, they may not co-move with consumer inflation that investors aim to hedge (Armann and Weisdorf (2008)). Moreover, some incentive regimes do not automatically adjust for inflation, e.g. rate freezes, and thus do not protect against inflationary shocks.

Despite the overall low share of variable input costs, some infrastructure firms face inflation exposure on the cost side. For example, merchant power generators are directly exposed to energy prices. Transport infrastructure firms are indirectly affected by rising energy prices as traffic volumes falter when oil prices rise. Even when infrastructure assets generate inflation-linked cash flows, these do not necessarily materialize for equity investors as debt financing is a significant cost component for infrastructure firms with high gearing levels. Rising inflation increases uncertainty and therefore debt risk premiums. If refinancing is required during an inflationary period the inflation hedging characteristics are taken out (Euromoney (2006)), rendering highly leveraged assets less effective hedges against inflation (Williams (2007)). Furthermore, if infrastructure firms issue inflation-linked bonds, the inflation hedging properties of the equity side deteriorate (Armann and Weisdorf (2008)). This phenomenon could well be the case in some mature inflation trading markets such as the U.K., where utilities account for a significant share of the inflation-linked corporate bond market.

7.4.2 Investor implications

It seems that anecdotal evidence about select infrastructure assets with high pricing power, favorable regulatory regimes and low input price exposure have been generalized in the investment community into the belief that infrastructure in general is a good inflation hedge. The empirical analysis shows that this hypothesis cannot be corroborated on empirical grounds. Though investors are not protected against inflation by investing in general infrastructure, certain infrastructure assets that are characterized by high entry barriers, vertical integration, and a concentrated market structure may nevertheless provide a quite effective hedge. This finding implies that investors who are looking for such inflation hedges need to have the appropriate due diligence capabilities to identify those assets that have particularly strong market positions, operate under a favorable regulatory regime, and are characterized by high market entry barriers and vertical integration. Hence, an in-depth understanding of the particular market dynamic, the business model and the regulatory environment is indispensable since even for the same asset types inflation hedging characteristics may differ. For example, buying a port company may not give the same inflation hedging as buying a concession to build a dock, where governments may grant inflation-linked cash flows (Euromoney (2006)). Investors seeking long-term inflation protection should carefully select infrastructure assets with strong pricing power and depart from the belief that infrastructure generally provides a natural hedge. This restriction limits the infrastructure investment opportunities in the sample to \$1.1 trillion relative to the total infrastructure market capitalization of \$3.8 trillion at the end of 2009.

7.4.3 Limitations

The above analysis has some limitations, which could be addressed by future research. The analysis is primarily focused on inflation correlation and not on real return targets or correlations with other assets in the investor's portfolio. Though this analysis is based on the most comprehensive infrastructure dataset yet analyzed, the time series and emerging market coverage is limited in comparison to studies analyzing other assets because infrastructure is a relatively new asset class. Most importantly, this analysis cannot unveil the behavior of infrastructure returns in high inflation environments above 21%. Moreover, the infrastructure dataset only represents listed infrastructure firms and is confined to the economic infrastructure sectors telecommunication, transport, and utilities. Further studies are required to analyze the inflation hedging features of unlisted infrastructure firms, social infrastructure assets, and PPP projects. Particularly, the inflation hedging characteristics of PPPs and social infrastructure assets may differ as the contractual structures between the operators and governments often embed an explicit inflation link. Lastly, this analysis only provides ad-hoc explanations for the limited inflation hedging and future research will have to uncover their relevance.

7.5 Synopsis

This analysis contributes to the emerging research on the inflation hedging qualities of infrastructure, where empirical evidence is limited. A proprietary dataset of 824 listed infrastructure firms in conjunction with a comprehensive set of inflation data across 46 countries and 37 years is used to provide a robust insight into this important investment feature. The estimation procedure with spatial correlation consistent standard errors according to Driscoll and Kraay (1998) and a correction for over-lapping data according to Britten-Jones et al. (2011) addresses the methodological shortcomings of previous research. In contrast to the widespread belief that infrastructure is a natural hedge against inflation, the results suggest that domestic infrastructure in general does not hedge inflation better than domestic equities. Domestic listed infrastructure as well as any of the subsectors telecom, transport, and utilities hedge inflation just as good (or bad) as other equities. Only for infrastructure portfolios of firms with particularly high pricing power the analysis reveals slightly superior (and fairly good) hedging qualities at a five year investment horizon relative to equities and average infrastructure. In summary, the proposition of enhanced inflation hedging based on the monopolistic market positions, favorable regulatory regimes, and the limited operating cost exposure seems not to materialize for all infrastructure assets, except for those with particularly high pricing power. As a consequence, investors shall conduct significant due diligence in selecting infrastructure assets to hedge inflation.

Chapter 8

Conclusion

8.1 Summary

In this thesis I analyze the investment risk profile (hypotheses H1.1 and H1.2), the impact of regulation on risk (H2.1, H2.2, and H2.3), and the inflation hedging properties (H3.1) of a sample of listed infrastructure firms. The results

- point out that the significant idiosyncratic risks of infrastructure assets such as construction risk, operating leverage, discretionary regulation, and the lack of product diversification, contribute to a total corporate risk exposure that is similar to other industries (H1.1),
- confirm the low market risk exposure and thus the diversification benefits of infrastructure (H1.2),
- reaffirm Peltzman's buffering hypothesis that price regulation reduces systematic risk (H2.1),
- highlight the relevance of independent regulation in rendering incentive regulation effective in transferring risk onto regulated firms (H2.2),
- demonstrate that the presence of independent regulatory institutions entails lower systematic risk and thus lower cost of capital (H2.3),

- show that the commonly believed inflation hedging properties do not apply to all infrastructure assets, but only to those characterized by strong market positions, vertical integration, and high entry barriers (H3.1).

This thesis contributes to the literature on the characteristics of private infrastructure investments. It provides an analysis of the often cited hypothesis that infrastructure is low risk using a robust methodology and a large, cross-sector, and global dataset of firms that derive at least 50% of their revenues from physical infrastructure assets. While low market risk is corroborated for most sectors, the finding of significant exposure to idiosyncratic risks and the empirical identification of the underlying risk factors (construction risk, operating leverage, little diversification, regulatory risk) challenges the conventional investor wisdom that infrastructure is generally low risk. Moreover, the results allude to the significant heterogeneity in the risk profiles of different infrastructure sectors. Secondly, this thesis complements the political economy literature on price regulation. It extends the affirmative evidence on the Peltzman hypothesis to a cross-country, cross-sector dataset of 764 infrastructure firms for a deregulated market context. The literature on the impact of the regulatory regime, which previously received little attention and where empirical results are ambiguous, is supplemented by providing evidence that incentive regulation does indeed increase systematic risk, but only if implemented by independent regulatory authorities. To the best of my knowledge, this is the first study that investigates the effect of regulatory independence on systematic risk, and shows that the presence of independent regulators reduces systematic risk and thus cost of capital. The implication of both findings – namely that independent regulators avert regulatory capture and thus render incentive regulation effective, and that they signal regulatory commitment and thus reduce regulatory uncertainty – provides a further lesson on the beneficial role of independent regulatory authorities. Lastly, this thesis contributes to the inflation hedging literature of different asset classes by analyzing infrastructure with a sound statistical methodology with spatial correlation consistent standard errors and a correction for over-lapping data. In contrast to previous work the analysis is based on a sufficiently long time series of 37 years and data across 46 countries and all infrastructure sectors. The results challenge the conventional investor wisdom that infrastructure in general is a natural inflation hedge on empirical grounds. However, it also provides evidence that select infrastructure assets with particularly high pricing power – characterized by strong market positions, high entry barriers, and vertical integration – may offer an enhanced inflation hedge in comparison to equities.

The above results contribute to an improved understanding of the infrastructure risk characteristics for both investment strategy and public policy. The insights enable investors to better assess the peculiar risk features of infrastructure assets and provide guidance for effective fund allocation. The low systematic risk exposure highlights the diversification benefits that infrastructure potentially offers. To address the significant idiosyncratic risks, investors should follow a sophisticated approach to infrastructure investing including appropriate risk management strategies and methodologies such as simulation-based real-option valuation tools. Moreover, the use of financial intermediaries (e.g. funds, insurance), an adequate project structure with efficient risk allocations between the public and the private sector, and appropriate government support mechanisms are key to success. The diversity of the risk and inflation hedging features of different infrastructure sectors, markets, and assets imply that investors need to acquire profound analysis and investment selection capabilities in order to invest in those assets that provide the desired investment characteristics. Due to the significant impact of price regulation, the regulatory regime, and regulatory independence, investors should also develop a thorough understanding of the employed regulatory mechanisms and their interactions within the policy and institutional framework. The improved understanding of infrastructure investments may lessen the information gap that many investors face today and thus contribute to attracting additional funds to the asset class.

The findings also provide lessons for public policy. They emphasize the critical role of independent regulatory authorities in rendering incentive regulation effective and in increasing regulatory commitment. Policy makers should therefore strive for an institutionalization of regulatory independence and a better endowment of regulators with staff and financial resources, particularly in emerging countries and the transportation sector where progress is insufficient. The results also point out that governmental financial support schemes (e.g. guarantees) may be warranted for socially beneficial infrastructure projects if idiosyncratic risks along with insufficient diversification impede investments. Since resource-constrained governments are unlikely to provide sufficient finance for the massive infrastructure requirements, instituting these conducive policies of regulatory independence and risk mitigation mechanisms may contribute to closing the looming infrastructure financing gap.

8.2 Future directions

The analyses in this thesis provide scope for further research. The research questions may be reinvestigated using different datasets or may be extended to a more detailed level of analysis. Future research could take advantage of samples with larger cross-sections, longer time series, additional infrastructure sectors, and different investment vehicles. Due to the ongoing infrastructure privatization, prospective studies may benefit from larger cross-sections with regard to geographic and sector representation. This is of particular relevance to the transportation sector where private involvement is still limited relative to other sectors, particularly in certain regions such as North America. Similarly, emerging market representation is poor for some subsectors. Besides an enlarged cross-section, an extended time series also makes future analyses worthwhile. As previous research finds that the inflation hedging properties differ depending on the magnitude of inflation, the analysis of longer infrastructure return time series including high inflation phases may yield valuable conclusions. In addition, an analysis of social infrastructure assets such as prisons, hospitals, and schools could provide insights into their supposedly distinct risk properties relative to economic infrastructure. Future research may also investigate the investment characteristics of other infrastructure investment vehicles such as listed or unlisted funds, direct investments, and Public-Private Partnerships. Moreover, there is little research on the risk features of debt instruments used in infrastructure finance, including project bonds, corporate bonds, project finance loans, and bank loans.

Prospective studies may analyze further firm-level determinants of the infrastructure risk properties or other features of infrastructure firms. For this purpose the collected dataset of pure-play infrastructure firms provides a useful starting point, since empirical research on infrastructure has so far been restricted due to a lack of data availability. Firm-level variables that are of interest include operational asset characteristics (e.g. the traffic structure within transport, the generation technology for electricity), financial policies, ownership structure, and the life cycle stage. In particular, an analysis of brownfield vs. greenfield infrastructure may yield relevant results for re-financing decisions. Other regulatory variables such as the regulators' financial and staff resources, the detailed features of the regulatory regime (e.g. regulatory lags, quality standards, universal service obligations), and the actual independence of regulators (i.e. separating de-facto and de-iure independence) could advance the existing political economy literature.

A final remark concerns the extent to which these results can be extrapolated into the future. As infrastructure is still a young equity segment, the asset class will evolve further in the future. The scope of investment opportunities is growing due to the high infrastructure financing need both in emerging and developed markets (OECD (2007)), the ongoing privatization trend, and the emerging secondary asset market. Infrastructure assets may also attract additional demand once the asset class becomes more familiar to the larger investment community. The continuously evolving business and financing models for infrastructure delivery could also impact the risk properties of infrastructure. Finally, the increasing maturity of regulatory authorities and the evolvement of regulatory frameworks could lead to a shift in the risk allocation between firms, governments, and consumers.

Appendix

Table 8.1: SIC codes, names, and definitions (I)

Code	Name	Definition
Transportation		
4011	Railroads, Line-Haul Operating	Establishments primarily engaged in line-haul railroad passenger and freight operations. Railways primarily engaged in furnishing passenger transportation confined principally to a single municipality, contiguous municipalities, or a municipality and its suburban areas are classified in Major Group 41. Includes: Electric railroads, line-haul operating. Interurban railways. Railroads, line-haul operating.
4013	Railroad Switching And Terminal Establishments	Establishments primarily engaged in the furnishing of terminal facilities for rail passenger or freight traffic for line-haul service, and in the movement of railroad cars between terminal yards, industrial sidings and other local sites. Terminal companies do not necessarily operate any vehicles themselves, but may operate the stations and terminals. Lessors of railway property are classified in Real Estate, Industry 6517. Includes: Belt line railroads. Logging railroads. Railroad terminals. Stations operated by railway terminal companies.
4111	Local And Suburban Transit	Establishments primarily engaged in furnishing local and suburban mass passenger transportation over regular routes and on regular schedules, with operations confined principally to a municipality, contiguous municipalities, or a municipality and its suburban areas. Also included in this industry are establishments primarily engaged in furnishing passenger transportation by automobile, bus, or rail to, from, or between airports or rail terminals, over regular routes, and those providing bus and rail commuter services. Includes: Airport limousine scheduled service. Airport transportation service, local: road or rail. Bus line operation, local. Cable cars, except aerial, amusement and scenic. City and suburban bus line operation. Commuter bus operation. Commuter rail passenger operation. Elevated railway operation. Local railway passenger operation. Monorails, regular route: except amusement and scenic. Passenger transportation, regular route, road or rail: between airports. Streetcar operation. Suburban and urban railway operation. Subway operation. Trolley operation, except amusement and scenic.
4119	Local Passenger Transportation, Not Elsewhere Classified	Establishments primarily engaged in furnishing miscellaneous passenger transportation, where such operations are principally within a municipality, contiguous municipalities, or a municipality and its suburban areas. Establishments primarily engaged in renting passenger automobiles without drivers are classified in Services, Industry Group 751. Establishments primarily operating ski lifts, tows, and other recreational lifts are classified in Services, Industry 7999. Includes: Aerial tramways, except amusement and scenic. Ambulance service, road. Automobile rental with drivers. Cable cars, aerial: except amusement and scenic. Cog railways, except amusement and scenic. Hearse rental with drivers. Limousine rental with drivers. Sight-seeing buses. Vanpool operation.
4173	Terminal And Service Facilities For Motor Vehicle Passenger Transport	Establishments primarily engaged in the operation of motor vehicle passenger terminals and of maintenance and service facilities, not operated by companies that also furnish motor vehicle passenger transportation. Establishments that are owned by motor vehicle passenger transportation companies and are primarily engaged in operating terminals for use of such vehicles are classified in the same industry as the establishments providing the motor vehicle transportation. Separate maintenance and service facilities operated by companies furnishing motor vehicle passenger transportation should be treated as auxiliaries. Establishments which provide motor vehicle maintenance or service for the general public are classified in Services, Industry Group 753. Includes: Bus terminal operation. Maintenance facilities for motor vehicle passenger transportation.
4231	Terminal And Joint Terminal Maintenance Facilities For Motor Freight	Establishments primarily engaged in the operation of terminal facilities used by highway-type property carrying vehicles. Also included are terminals which provide maintenance and service for motor vehicles. Terminals operated by motor freight transportation companies for their own use are classified in Industry Group 421. Separate maintenance and service facilities operated by motor freight transportation companies are classified as auxiliary. Establishments primarily engaged in the repair of trucks are classified in Services, Industry Group 753. Includes: Freight trucking terminals, with or without maintenance facilities.
4491	Marine Cargo Handling	Establishments primarily engaged in activities directly related to marine cargo handling from the time cargo, for or from a vessel, arrives at shipside, dock, pier, terminal, staging area, or in-transit area until cargo loading or unloading operations are completed. Included in this industry are establishments primarily engaged in the transfer of cargo between ships and barges, trucks, trains, pipelines, and wharfs. Cargo handling operations carried on by transportation companies and separately reported are classified here. This industry includes the operation and maintenance of piers, docks, and associated buildings and facilities; but lessors of such facilities are classified in Real Estate, Industry 6512. Includes: Docks, including buildings and facilities: operation and maintenance. Loading vessels. Marine cargo handling. Piers, including buildings and facilities: operation and maintenance. Ship hold cleaning. Stevedoring. Unloading vessels. Waterfront terminal operation.
4493	Marinas	Establishments primarily engaged in operating marinas. These establishments rent boat slips and store boats, and generally perform a range of other services including cleaning and incidental boat repair. They frequently sell food, fuel, and fishing supplies, and may sell boats. Establishments primarily engaged in building or repairing boats and ships are classified in Manufacturing, Industry Group 373. Establishments primarily engaged in the operation of charter or party fishing boats or rental of small recreational boats are classified in Services, Industry 7999. Includes: Boat yards, storage and incidental repair. Marinas. Marine basins, operation of. Yacht basins, operation of.

Source: Author (based on SIC code definitions)

Table 8.2: SIC codes, names, and definitions (II)

Code	Name	Definition
Transportation		
4581	Airports, Flying Fields, And Airport Terminal Services	Establishments primarily engaged in operating and maintaining airports and flying fields; in servicing, repairing (except on a factory basis), maintaining, and storing aircraft; and in furnishing coordinated handling services for airfreight or passengers at airports. This industry also includes private establishments primarily engaged in air traffic control operations. Government air traffic control operations are classified in Public Administration, Industry 9621. Aircraft modification centers and establishments primarily engaged in factory type overhaul of aircraft are classified in Manufacturing, Major Group 37, and flying fields maintained by aviation clubs are classified in Services, Industry 7997. Includes: Air traffic control, except government. Aircraft cleaning and janitorial service. Aircraft servicing and repairing, except on a factory basis. Aircraft storage at airports. Aircraft upholstery repair. Airfreight handling at airports. Airport hangar rental. Airport leasing, if operating airport. Airport terminal services. Airports. Flying fields, except those maintained by aviation clubs. Hangar operation.
4785	Fixed Facilities And Inspection And Weighing Services For Motor Vehicles	Establishments primarily engaged in the inspection and weighing of goods in connection with transportation or in the operation of fixed facilities for motor vehicle transportation, such as toll roads, highway bridges, and other fixed facilities, except terminals. Includes: Cargo checkers and surveyors, marine. Highway bridges, operation of. Inspection services connected with transportation. Toll bridge operation. Toll roads, operation of. Tunnel operation, vehicular. Weighing services connected with transportation.
4612	Crude Petroleum Pipelines	Establishments primarily engaged in the pipeline transportation of crude petroleum. Field gathering lines are classified in Mining, Major Group 13. Includes: Crude petroleum pipelines.
4613	Refined Petroleum Pipelines	Establishments primarily engaged in the pipeline transportation of refined products of petroleum, such as gasoline and fuel oil. Includes: Gasoline pipelines, common carriers. Refined petroleum pipelines.
4619	Pipelines, Not Elsewhere Classified	Establishments primarily engaged in the pipeline transportation of commodities, except crude petroleum, refined products of petroleum, and natural gas. Establishments primarily engaged in the pipeline transportation of refined petroleum are classified in Industry 4613, and those engaged in natural gas transmission are classified in Industry 4922. Includes: Coal pipeline operation. Pipeline operation except petroleum and natural gas pipelines. Slurry pipeline operation.
5171	Petroleum Bulk Stations And Terminals	Establishments primarily engaged in the wholesale distribution of crude petroleum and petroleum products from bulk liquid storage facilities. These establishments have a bulk liquid storage capacity of 10,000 gallons or more. Establishments primarily engaged in the wholesale distribution of crude petroleum and petroleum products without bulk liquid storage facilities are classified in Industry 5172.
Telecommunication		
4812	Radiotelephone Communications	Establishments primarily engaged in providing two-way radiotelephone communications services, such as cellular telephone services. This industry also includes establishments primarily engaged in providing telephone paging and beeper services and those engaged in leasing telephone lines or other methods of telephone transmission, such as optical fiber lines and microwave or satellite facilities, and reselling the use of such methods to others. Establishments primarily engaged in furnishing telephone answering services are classified in Services, Industry 7389. Includes: Beeper (radio pager) communications services. Cellular telephone services. Paging services: radiotelephone. Radiotelephone communications.
4813	Telephone Communications, Except Radiotelephone	Establishments primarily engaged in furnishing telephone voice and data communications, except radiotelephone and telephone answering services. This industry also includes establishments primarily engaged in leasing telephone lines or other methods of telephone transmission, such as optical fiber lines and microwave or satellite facilities, and reselling the use of such methods to others. Establishments primarily engaged in furnishing radiotelephone communications are classified in Industry 4812, and those furnishing telephone answering services are classified in Services, Industry 7389. Includes: Data telephone communications. Local telephone communications, except radio telephone. Long distance telephone communications. Voice telephone communications, except radio telephone.
4822	Telegraph And Other Message Communications	Establishments primarily engaged in furnishing telegraph and other nonvocal message communications services, such as cablegram, electronic mail, and facsimile transmission services. Includes: Cablegram services. Electronic mail services. Facsimile transmission services. Mailgram services. Photograph transmission services. Radio telegraph services. Telegram services. Telegraph cable services. Telegraph services. Teletypewriter services. Telex services.
4832	Radio Broadcasting Stations	Establishments primarily engaged in broadcasting aural programs by radio to the public. Included in this industry are commercial, religious, educational, and other radio stations. Also included here are establishments primarily engaged in radio broadcasting and which produce radio program materials. Separate establishments primarily engaged in producing radio program materials are classified in Services, Industry 7922. Radio Broadcasting Stations, Music Format. Radio Broadcasting Stations, Except Music Format.

Source: Author (based on SIC code definitions)

Table 8.3: SIC codes, names, and definitions (III)

Code	Name	Definition
Telecommunication		
4833	Television Broadcasting Stations	Establishments primarily engaged in broadcasting visual programs by television to the public, except cable and other pay television services. Included in this industry are commercial, religious, educational, and other television stations. Also included here are establishments primarily engaged in television broadcasting and which produce taped television program materials. Separate establishments primarily engaged in producing taped television program materials are classified in Services, Industry 7812. Establishments primarily engaged in furnishing cable and other pay television services are classified in Industry 4841. Includes: Television broadcasting stations.
4841	Cable And Other Pay Television Services	Establishments primarily engaged in the dissemination of visual and textual television programs, on a subscription or fee basis. Included in this industry are establishments which are primarily engaged in cablecasting and which also produce taped program materials. Separate establishments primarily engaged in producing taped television or motion picture program materials are classified in Services, Industry 7812. Includes: Cable television services. Closed circuit television services. Direct broadcast satellite (DBS) services. Multipoint distribution systems (MDS) services. Satellite master antenna systems (SMATV) services. Subscription television services.
4899	Communications Services, Not Elsewhere Classified	Establishments primarily engaged in furnishing communications services, not elsewhere classified. Establishments primarily engaged in providing on-line information retrieval services on a contract or fee basis are classified in Services, Industry 7375. Includes: Radar station operation. Radio broadcasting operated by cab companies. Satellite earth stations. Satellite or missile tracking stations, operated on a contract basis. Tracking missiles by telemetry and photography on a contract basis.
Utilities		
4911	Electric Services	Establishments engaged in the generation, transmission, and/or distribution of electric energy for sale. Includes: Electric power generation, transmission, or distribution.
4922	Natural Gas Transmission	Establishments engaged in the transmission and/or storage of natural gas for sale. Includes: Natural gas storage. Natural gas transmission. Pipelines, natural gas.
4923	Natural Gas Transmission And Distribution	Establishments engaged in both the transmission and distribution of natural gas for sale. Includes: Natural gas transmission and distribution.
4924	Natural Gas Distribution	Establishments engaged in the distribution of natural gas for sale. Includes: Natural gas distribution.
4925	Mixed, Manufactured, Or Liquefied Petroleum Gas Production And/Or	Establishments engaged in the manufacture and/or distribution of gas for sale, including mixtures of manufactured with natural gas. Establishments distributing liquefied petroleum (LP) gas in steel containers are classified in Retail Trade, Industry 5984. Includes: Blue gas, carbureted: production and distribution. Coke oven gas, production and distribution. Coke ovens, by-product: operated for manufacture or distribution. Gas, mixed natural and manufactured: production and distribution. Liquefied petroleum (LP) gas, distribution through mains. Manufactured gas production and distribution. Synthetic natural gas from naphtha, production and distribution.
4931	Electric And Other Services Combined	Establishments primarily engaged in providing electric services in combination with other services, with electric services as the major part though less than 95 percent of the total. Includes: Electric and other services combined (electric less than 95 percent of total).
4932	Gas And Other Services Combined	Establishments primarily engaged in providing gas services in combination with other services, with gas services as the major part though less than 95 percent of the total. Includes: Gas and other services combined (gas less than 95 percent of total).
4939	Combination Utilities, Not Elsewhere Classified	Establishments primarily engaged in providing combinations of electric, gas, and other services, not elsewhere classified. Combination of Utilities.
4941	Water Supply	Establishments primarily engaged in distributing water for sale for domestic, commercial, and industrial use. Systems distributing water primarily for irrigation service are classified in Industry 4971. Includes: Water supply systems, except irrigation.
4952	Sewerage Systems	Establishments primarily engaged in the collection and disposal of wastes conducted through a sewer system, including such treatment processes as may be provided. Includes: Sewerage systems.
4961	Steam And Air-Conditioning Supply	Establishments engaged in the production and/or distribution of steam and heated or cooled air for sale. Includes: Air-conditioning supply services. Cooled air suppliers. Distribution of cooled air. Geothermal steam production. Steam heating systems (suppliers of heat). Steam supply systems, including geothermal.
4971	Irrigation Systems	Establishments primarily engaged in operating water supply systems for the purpose of irrigation. Establishments primarily engaged in operating irrigation systems for others, but which do not themselves provide water, are classified in Agricultural Services, Industry 0721. Includes: Impounding reservoirs, irrigation. Irrigation system operation. Water distribution or supply systems for irrigation.

Source: Author (based on SIC code definitions)

Table 8.4: GICS codes, names, and definitions

Code	Name	Definition
Transportation		
20304010	Railroads	Companies providing primarily goods and passenger rail transportation
20305010	Airport Services	Operators of airports and companies providing related services
20305020	Highways & Railtracks	Owners and operators of roads, tunnels and railtracks
20305030	Marine Ports & Services	Owners and operators of marine ports and related services
10102040	Oil & Gas Storage & Transportation	Companies engaged in the storage and/or transportation of oil, gas and/or refined products. Includes diversified midstream natural gas companies, oil and refined product pipelines, coal slurry pipelines and oil & gas shipping companies
Telecommunication		
50101010	Alternative Carriers	Providers of communications and high-density data transmission services primarily through a high bandwidth/fiber-optic cable network
50101020	Integrated Telecommunication Services	Operators of primarily fixed-line telecommunications networks and companies providing both wireless and fixed-line telecommunications services not classified elsewhere
50102010	Wireless Telecommunication Services	Providers of primarily cellular or wireless telecommunication services, including paging services
25401025	Cable & Satellite	Providers of cable or satellite television services. Includes cable networks and program distribution
Utilities		
55101010	Electric Utilities	Companies that produce or distribute electricity. Includes both nuclear and non-nuclear facilities
55102010	Gas Utilities	Companies whose main charter is to distribute and transmit natural and manufactured gas. Excludes companies primarily involved in gas exploration or production classified as 'Oil & Gas Exploration & Production' and diversified midstream natural gas companies classified as 'Oil & Gas Storage & Transportation'
55103010	Multi-Utilities	Utility companies with significantly diversified activities in addition to core Electric Utility, Gas Utility and/or Water Utility operations
55104010	Water Utilities	Companies that purchase and redistribute water to the end-consumer. Includes large-scale water treatment systems
55105010	Independent Power Producers & Energy Traders	Companies that operate as Independent Power Producers (IPPs), Gas & Power Marketing & Trading Specialists and/or Integrated Energy Merchants. Excludes electric transmission companies and utility distribution companies classified as 'Electric Utilities'

Source: Author (based on GICS code definitions)

Table 8.5: Country classification and TDS datatypes for country data

Country	Region	Development	Currency TDS Mnemonic	Local index TDS Mnemonic	Interest rate TDS Mnemonic
Argentina	Latin America	emerging	TDARSSP	MSARGTL	AGIBPES
Australia	Asia-Pacific	emerging	TDAUDSP	MSAUSTL	AUSIB3M
Austria	Western Europe	developed	TDEURSP	MSASTRL	EIBOR3M
Bahrain	Mid-East	emerging	TDBHDSP	MSBAHDL	FRTBS3M
Bangladesh	Asia-Pacific	emerging	TDBDTSP	IFFMBGL	INPTB91
Belgium	Western Europe	developed	TDEURSP	MSBELGL	EIBOR3M
Bermuda	North America	emerging	TDBMDSP	MSUSAML	FRTBS3M
Brazil	Latin America	emerging	TDBRLSP	MSBRAZL	BRCDB3M
Canada	North America	developed	TDCADSP	MSCNDAL	CDN3MTB
Cayman Islands	North America	emerging	TDKYDSP	MSUSAML	FRTBS3M
Chile	Latin America	emerging	TDCLPSP	MSCHILL	CLCD90D
China	Asia-Pacific	emerging	TDCNYSP	MSCHINL	CHIB3MO
Colombia	Latin America	emerging	TDCOPSP	MSCOLML	CBFTDEP
Croatia	Eastern Europe	emerging	TDHRKSP	MSCROAL	EIBOR3M
Czech Republic	Eastern Europe	emerging	TDCZKSP	MSCZCHL	PRIBK3M
Denmark	Western Europe	developed	TDDKKSP	MSDNMKL	CIBOR3M
Egypt	Africa	emerging	TDEGPSP	MSEGYTL	EYTBL3M
Estonia	Eastern Europe	emerging	TDEEKSP	MSESTNL	EOIBK3M
Finland	Western Europe	developed	TDEURSP	MSFINDL	FNIBF3M
France	Western Europe	developed	TDEURSP	MSFRNCL	EIBOR3M
Germany	Western Europe	developed	TDEURSP	MSGERML	EIBOR3M
Greece	Western Europe	developed	TDEURSP	MSGDEEL	EIBOR3M
Hong Kong	Asia-Pacific	developed	TDHKDSP	MSHGKGL	HKIBK3M
Hungary	Eastern Europe	emerging	TDHUFSP	MSHUNGL	HNIBK3M
India	Asia-Pacific	emerging	TDINRSP	MSINDIL	INPTB91
Indonesia	Asia-Pacific	emerging	TDIDRSP	MSINDFL	IDDEP3M
Ireland	Western Europe	developed	TDEURSP	MSEIREL	EIBOR3M
Israel	Mid-East	emerging	TDILSSP	MSISRAL	IS3MTBL
Italy	Western Europe	developed	TDEURSP	MSITALL	EIBOR3M
Japan	Asia-Pacific	developed	TDJPYSP	MSJPANL	JPIBO3M
Jordan	Mid-East	emerging	TDJODSP	MSJORDL	FRTBS3M
Kenya	Africa	emerging	TDKESSP	MSKNYAL	KNREPON
Korea (South)	Asia-Pacific	emerging	TDKRWSP	MSKOREL	KOCD91D
Kuwait	Mid-East	emerging	TDKWDSP	MSKUWDL	FRTBS3M
Latvia	Eastern Europe	emerging	TDLVLSP	IFFMLAL	LVIBK3M
Lithuania	Eastern Europe	emerging	TDLTLSP	IFFMLIL	EOIBK3M
Luxembourg	Western Europe	developed	TDEURSP	MSEROPE	EIBOR3M
Malaysia	Asia-Pacific	emerging	TDMYRSP	MSMALFL	MYIBK3M
Malta	Western Europe	emerging	TDEURSP	DJMALTE	EIBOR3M
Mexico	Latin America	emerging	TDMXNSP	MSMEXFL	MXCTC91
Morocco	Africa	emerging	TDMADSP	MSMORCL	MDDEP3M
Netherlands	Western Europe	developed	TDEURSP	MSNETHL	EIBOR3M
New Zealand	Asia-Pacific	developed	TDNZDSP	MSNZEAL	NZIBK3M
Nigeria	Africa	emerging	TDNGNSP	MSNGRAL	KNREPON
Norway	Western Europe	developed	TDNOKSP	MSNWAYL	NWIBK3M
Oman	Mid-East	emerging	TDOMRSP	MSOMADL	FRTBS3M
Pakistan	Asia-Pacific	emerging	TDPKRSP	MSPAKIL	PKREP90
Peru	Latin America	emerging	TDPENSP	MSPERUL	PSDP180
Philippines	Asia-Pacific	emerging	TDPHPSP	MSPHLFL	PHTBL3M
Poland	Eastern Europe	emerging	TDPLNSP	MSPLNDL	POWIB3M
Portugal	Western Europe	developed	TDEURSP	MSPORDL	EIBOR3M
Qatar	Mid-East	emerging	TDQARSP	MSQATDL	FRTBS3M
Romania	Eastern Europe	emerging	TDRONSP	MSROMNL	RMIBK3M
Russia	Asia-Pacific	emerging	TDRUBSP	MSRUSSL	RSIBK90
Saudi Arabia	Mid-East	emerging	TDSARSP	MSSARDL	FRTBS3M
Singapore	Asia-Pacific	developed	TDSGDSP	MSSINGL	SNGTB3M
Slovakia	Eastern Europe	emerging	TDSKKSP	IFFMSOL	SXIBK3M
Slovenia	Eastern Europe	emerging	TDEURSP	MSSLVNL	EIBOR3M
South Africa	Africa	emerging	TDZARSP	MSSARFL	SATBL3M
Spain	Western Europe	developed	TDEURSP	MSSPANL	EIBOR3M
Sri Lanka	Asia-Pacific	emerging	TDLKRSP	MSSRILL	SRTBL3M
Sweden	Western Europe	developed	TDSEKSP	MSSWDNL	SDTB90D
Switzerland	Western Europe	developed	TDCHFSP	MSSWITL	SWIBK3M
Taiwan	Asia-Pacific	emerging	TDTWDSP	MSTAIWL	TAMM90D
Thailand	Asia-Pacific	emerging	TDTHBSP	MSTHAFL	THBTRP3
Turkey	Eastern Europe	emerging	TDTRYSP	MSTURKL	TKIBK3M
United Arab Emirates	Mid-East	emerging	TDAEDSP	MSUAEDL	FRTBS3M
United Kingdom	Western Europe	developed	TDGBPSP	MSUTDKL	LDNIB3M
United States	North America	developed	TDUSDSP	MSUSAML	FRTBS3M
Venezuela	Latin America	emerging	TDVEFSP	TOTMKVE	VEDP90D
Vietnam	Asia-Pacific	emerging	TDVNDSP	MSVIETL	THBTRP3
Zimbabwe	Africa	emerging	TDZWDSP	MSSARFL	n/a

Source: Author

Table 8.6: Corporate risk metrics in USD

	Return	**Volatility**	**Getmansky-Volatility**	**Skewness**	**Skewness 2**	**Excess Kurtosis**	**Excess Kurtosis 2**
	Med, 35yr, $ in %	*Med, 35yr, $ in %*	*Med, 35yr, $ in %*	*Med, 35yr, $*	*Med, 35yr, $*	*Med, 35yr, $*	*Med, 35yr, $*
MSCI	12.5	39.8	41.0	-0.18	0.01	-0.84	0.12
Infrastructure	8.8 ***	42.6	40.6	-0.05 ***	0.02	-0.23 ***	0.20 ***
Telecommunication	2.5 ***	55.5 ***	57.3 ***	-0.09 ***	-0.01 ***	-0.47 ***	0.20 ***
Transport	7.6 ***	41.1	39.3	-0.07 ***	0.01	-0.35 **	0.20 ***
Utilities	10.4 ***	35.5 ***	32.4 ***	-0.01 ***	0.04 ***	0.07 ***	0.20 ***
Satellite	-5.9 ***	58.8 ***	68.0 ***	-0.08	-0.06 ***	-0.88	0.30 **
Wireless	4.9 ***	50.7 ***	53.4 ***	-0.08 ***	-0.01 *	-0.65	0.18 ***
Fixed-line	2.0 ***	57.9 ***	57.6 ***	-0.14	0.01 *	-0.17 ***	0.25 ***
Cable	4.9 ***	49.3 ***	55.2 ***	-0.04 **	-0.04 **	-0.87	0.12
Airports	7.0 ***	38.2	40.0	-0.43 **	-0.02	0.32	0.14
Ports	8.7 ***	46.8 ***	46.8	-0.05 *	0.02	-0.42	0.22 ***
Highways	7.9 **	39.0	35.4 **	-0.08	-0.02	-0.96	0.21 ***
Railroads	7.5 ***	31.9 ***	27.3 ***	0.12 ***	0.01	-0.27 *	0.16
Pipelines	7.3 ***	51.9 ***	64.0 ***	-0.12	0.00	-0.06 *	0.33 ***
Electricity	9.7 ***	44.7	39.9	-0.04 ***	0.06 ***	-0.02 ***	0.23 ***
Water	10.7 **	32.0 ***	30.7 ***	0.11 ***	-0.03 *	-0.41	0.14
Gas	11.6	30.3 ***	26.7 ***	0.12 ***	0.02	0.35 ***	0.20 ***
Multi	11.1 ***	24.0 ***	20.4 ***	-0.15 **	0.02	0.36 ***	0.15 **

Note: This table is based on a sample of 1,460 infrastructure and 2,073 MSCI firms. The small deviation relative to the full sample using local currency data is due to the different availability of USD data on TDS. *Med (Avg)* indicates that the reported figure is the median (average) of the respective subsample distribution; *L ($)* indicates that the results are based on local (USD) currency data; *35yr (15yr, 5yr)* indicates that for each firm the maximum time series of up to 35 (15, 5) years is used for the computation; ***, ** and * indicate that the distribution of the respective subsample is statistically different from the MSCI reference sample at the 1%, the 5%, and the 10% levels, respectively, using a two-tailed Mann-Whitney test.
Source: Rothballer and Kaserer (2011)

Table 8.7: Corporate and systematic risk metrics based on sample averages

	Volatility	**Getmansky-Volatility**	**Local Beta**	**World Beta**	**International Beta**	**Local Dimson Beta**	**Local Asset Beta**
	Avg, 35yr, L in %	*Avg, 35yr, L in %*	*Avg, 35yr, L*	*Avg, 35yr, $*	*Avg, 35yr, $*	*Avg, 35yr, L*	*Avg, 35yr, L*
MSCI	41.8	42.9	1.03	1.11	1.05	1.07	0.73
Infrastructure	50.9	53.5	0.73 ***	0.84 ***	0.75 ***	0.90 ***	0.46 ***
Telecommunication	69.5 ***	73.0 ***	1.11 *	1.24	1.19	1.41	0.62 ***
Transport	44.0	48.4	0.68 ***	0.78 ***	0.69 ***	0.81 ***	0.45 ***
Utilities	42.8 ***	44.5 ***	0.54 ***	0.64 ***	0.54 ***	0.65 ***	0.38 ***
Satellite	66.5 ***	76.1 ***	1.19	1.35	1.26	1.59	0.67
Wireless	66.2 ***	70.2 ***	1.05 *	1.17	1.11	1.27	0.66 *
Fixed-line	72.8 ***	76.4 ***	1.19	1.33 *	1.28	1.60	0.62 ***
Cable	69.8 ***	67.3 ***	0.91	1.06	1.06	1.07	0.49 ***
Airports	36.6 *	42.2	0.76 ***	0.96	0.92	0.91 *	0.55 ***
Pipelines	60.0 ***	77.4 ***	0.75 ***	0.90 ***	0.82 ***	1.10	0.39 ***
Ports	47.8 ***	49.4 ***	0.69 ***	0.76 ***	0.64 ***	0.81 ***	0.55 ***
Highways	40.1	39.1	0.63 ***	0.74 ***	0.64 ***	0.66 ***	0.38 ***
Railroads	35.3 ***	36.7 ***	0.60 ***	0.66 ***	0.55 ***	0.66 ***	0.35 ***
Electricity	48.0	50.1	0.59 ***	0.71 ***	0.59 ***	0.74 ***	0.41 ***
Water	38.7 ***	40.4 ***	0.47 ***	0.48 ***	0.43 ***	0.58 ***	0.36 ***
Gas	38.1 ***	40.4 ***	0.48 ***	0.56 ***	0.48 ***	0.51 ***	0.35 ***
Multi	27.9 ***	27.8 ***	0.45 ***	0.47 ***	0.42 ***	0.44 ***	0.30 ***

Note: This table is based on the sample of 1,458 (1,460) infrastructure and 2,079 (2,073) MSCI firms for local currency (USD) data, except for asset beta. *Med (Avg)* indicates that the reported figure is the median (average) of the respective subsample distribution; *L ($)* indicates that the results are based on local (USD) currency data; *35yr (15yr, 5yr)* indicates that for each firm the maximum time series of up to 35 (15, 5) years is used for the computation; ***, ** and * indicate that the distribution of the respective subsample is statistically different from the MSCI reference sample at the 1%, the 5%, and the 10% levels, respectively, using a two-tailed Mann-Whitney test.
Source: Rothballer and Kaserer (2011)

Table 8.8: Corporate and systematic risk metrics for 15-years time series

	Volatility	**Getmansky-Volatility**	**Local Beta**	**World Beta**	**International Beta**	**Local Dimson Beta**	**Local Asset Beta**
	Med, 15yr, L in %	*Med, 15yr, L in %*	*Med, 15yr, L*	*Med, 15yr, $*	*Med, 15yr, $*	*Med, 15yr, L*	*Med, 15yr, L*
MSCI	38.6	38.8	0.99	1.07	1.00	1.03	0.68
Infrastructure	40.0	39.0	0.57 ***	0.70 ***	0.59 ***	0.64 ***	0.37 ***
Telecommunication	50.8 ***	52.1 ***	0.92 *	1.10	1.02	1.01	0.55 ***
Transport	39.1	40.7	0.57 ***	0.73 ***	0.57 ***	0.65 ***	0.37 ***
Utilities	33.4 ***	33.8 ***	0.40 ***	0.46 ***	0.39 ***	0.48 ***	0.28 ***
Satellite	55.9 ***	67.9 ***	0.91	1.15	1.11	1.08	0.60
Wireless	48.5 ***	45.9 ***	0.89 **	1.06	0.97	0.98	0.61 *
Fixed-line	55.9 ***	55.3 ***	0.96	1.15 **	1.06 *	1.02	0.52 ***
Cable	48.9 ***	53.9 ***	0.87 **	1.03	1.03	1.03	0.48 ***
Airports	36.0 *	38.6	0.79 ***	0.93	0.88	0.93	0.51 **
Pipelines	47.5 **	54.5 ***	0.57 ***	0.85 ***	0.67 ***	0.88	0.29 ***
Ports	45.6 ***	44.3 ***	0.61 ***	0.65 ***	0.49 ***	0.69 ***	0.49 ***
Highways	37.2	38.4	0.56 ***	0.65 ***	0.56 ***	0.51 ***	0.31 ***
Railroads	30.5 ***	27.5 ***	0.34 ***	0.43 ***	0.37 ***	0.42 ***	0.29 ***
Electricity	41.9	39.5	0.45 ***	0.54 ***	0.45 ***	0.55 ***	0.31 ***
Water	29.7 ***	30.1 ***	0.37 ***	0.33 ***	0.32 ***	0.40 ***	0.29 ***
Gas	28.6 ***	27.1 ***	0.35 ***	0.39 ***	0.34 ***	0.38 ***	0.23 ***
Multi	24.3 ***	24.2 ***	0.36 ***	0.39 ***	0.37 ***	0.35 ***	0.25 ***

Note: This table is based on the full sample of 1,458 infrastructure and 2,079 MSCI firms. *Med (Avg)* indicates that the reported figure is the median (average) of the respective subsample distribution; *L ($)* indicates that the results are based on local (USD) currency data; *35yr (15yr, 5yr)* indicates that for each firm the maximum time series of up to 35 (15, 5) years is used for the computation; ***, ** and * indicate that the distribution of the respective subsample is statistically different from the MSCI reference sample at the 1%, the 5%, and the 10% levels, respectively, using a two-tailed Mann-Whitney test.
Source: Rothballer and Kaserer (2011)

Table 8.9: Corporate and systematic risk metrics for 5-years time series

	Volatility	**Getmansky-Volatility**	**Local Beta**	**World Beta**	**International Beta**	**Local Dimson Beta**	**Local Asset Beta**
	Med, 5yr, L in %	*Med, 5yr, L in %*	*Med, 5yr, L*	*Med, 5yr, $*	*Med, 5yr, $*	*Med, 5yr, L*	*Med, 5yr, L*
MSCI	37.4	35.3	1.10	1.17	1.09	1.09	0.74
Infrastructure	36.1	34.8	0.61 ***	0.73 ***	0.61 ***	0.66 ***	0.40 ***
Telecommunication	41.6 ***	36.0	0.73 ***	0.89 ***	0.80 ***	0.74 ***	0.46 ***
Transport	39.9	38.9 **	0.66 ***	0.80 ***	0.69 ***	0.76 ***	0.45 ***
Utilities	32.4 ***	32.5 **	0.55 ***	0.64 ***	0.53 ***	0.60 ***	0.35 ***
Satellite	43.9 **	50.7 ***	0.84	0.85	0.78	1.14	0.59 **
Wireless	36.6	32.3	0.67 ***	0.81 ***	0.70 ***	0.71 ***	0.50 ***
Fixed-line	41.3 ***	35.9	0.76 ***	0.92 ***	0.84 ***	0.72 ***	0.43 ***
Cable	46.8 ***	46.2 **	0.78 ***	0.95 **	0.85	0.80 **	0.42 ***
Airports	37.7	38.4	0.82 ***	0.99	1.03	0.96 *	0.51 ***
Pipelines	46.3 ***	57.0 ***	0.81 ***	0.96 *	0.83 **	1.02	0.45 ***
Ports	48.5 ***	42.5 **	0.66 ***	0.77 ***	0.50 ***	0.76 ***	0.49 ***
Highways	41.4	36.0	0.61 ***	0.75 ***	0.54 ***	0.60 ***	0.38 ***
Railroads	29.9 ***	30.0 *	0.51 ***	0.62 ***	0.55 ***	0.60 ***	0.35 ***
Electricity	40.2 **	38.4 **	0.59 ***	0.69 ***	0.54 ***	0.65 ***	0.38 ***
Water	32.3 **	30.1 **	0.59 ***	0.55 ***	0.52 ***	0.55 ***	0.39 ***
Gas	26.3 ***	29.2 ***	0.47 ***	0.54 ***	0.47 ***	0.51 ***	0.27 ***
Multi	23.1 ***	23.0 ***	0.52 ***	0.58 ***	0.52 ***	0.49 ***	0.33 ***

Note: This table is based on the full sample of 1,458 infrastructure and 2,079 MSCI firms. *Med (Avg)* indicates that the reported figure is the median (average) of the respective subsample distribution; *L ($)* indicates that the results are based on local (USD) currency data; *35yr (15yr, 5yr)* indicates that for each firm the maximum time series of up to 35 (15, 5) years is used for the computation; ***, ** and * indicate that the distribution of the respective subsample is statistically different from the MSCI reference sample at the 1%, the 5%, and the 10% levels, respectively, using a two-tailed Mann-Whitney test.
Source: Rothballer and Kaserer (2011)

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