Essays in Infrastructure Investment

DISSERTATION

by

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1. Introduction

1.1 General Motivation

The importance of asset allocation is widely discussed in the academic literature and free of any controversy. It constitutes the essential foundation of investment decisions and is the main determinant of portfolio performance. However, there is no consensus on how much wealth should be allocated on a given asset class, as this depends on numerous variables such as return expectations, risk aversion, macroeconomic circumstances, illiquidity and the specific investment horizon. The original basis for asset allocation has been eroded during the last decade, as the traditionally main assets such as bonds, stocks and real estate have been affected by significant losses and are subject to considerable uncertainty. This makes it even more difficult for fund managers to decide how much wealth should be allocated to the various potential assets. Stock markets have suffered substantially through macroeconomic distortions reflected in high volatility and poor average performance. Bonds, which constitute a major share of institutional investment portfolios, are currently heavily influenced by growing governmental debt obligations. The former “save haven” of real estate was the main activator of the recent financial crisis and property markets lost substantially in value.

These impacts on investment portfolios have substantially altered investor perceptions and attitudes towards their original asset allocation strategy. In order to avoid further substantial losses as experienced during recent years, investors are now seeking sources of diversification to supplement core assets like stocks, bonds and real estate. In this context, private investments in infrastructure have been identified by many institutional investors as a viable alternative. The infrastructure asset universe can be divided into two main categories: economic and social infrastructure. Economic infrastructure includes long-lasting, large-scale physical structures like transportation and communication infrastructure, as well as energy and utility facilities. Social infrastructure, on the other hand, includes education, healthcare, waste disposal and judicial facilities. Despite this diversity and heterogeneity, infrastructure assets are considered to have attractive investment characteristics. The nature of infrastructure as a conservative, tangible and real asset seems to constitute a viable alternative to synthetic and complex financial products. Furthermore, due to their monopolistic nature, infrastructure investments are expected to provide stable and predictable long-term cash flows, which may enable investors to match their long-term liabilities. This monopolistic character and the provision of basic services, might induce cash flows which are less vulnerable to economic downturns than those from other, more cyclical assets. In consequence, infrastructure might be able to stabilize portfolio returns and reduce volatility. The private involvement in the infrastructure sector is driven by financial strains on governments, which render the public sector unable to guarantee adequate infrastructure provision. However, this imbalance between infrastructure provision and demand is expected to gain further momentum and increase privatization pressure over the long run. Nevertheless, despite the promising future infrastructure's track record and its investment history are still young, raising the question of whether infrastructure will really be able to meet optimistic investor expectations.

The infrastructure sector still lacks of professional structures and standardization at different levels and additionally faces a classification problem within the portfolio. Accordingly, infrastructure assets are often managed together with (seemingly) related assets like real estate. Short histories and a lack of good quality direct performance data still impede independent (academic) research and render infrastructure investment in-transparent, which in turn hinders investment. The objective of this dissertation is to deal with some of these shortcomings and to coherently analyze the role of direct infrastructure in a diversified portfolio, by using a novel set of direct infrastructure performance data. In order to provide robust and meaningful results, the dissertation deals with a number of different aspects which are important to the asset allocation management process. In particular, the investigation accounts for different markets, empirical models, expected returns, target rates, market phases, nominal and real returns, hedging abilities in the context of liabilities and systematic market risk. Furthermore, there is a specific and detailed focus on the relationship between real estate and infrastructure and on the relationship between direct and indirect infrastructure returns.

1.2 Research Question

The section provides a basic framework for this dissertation and the five articles, dealing with the related research questions for each.

The Interactions Between Direct and Securitized Infrastructure and its Relationship to Real Estate

- What are the contemporaneous correlations between direct and indirect infrastructure and other asset returns?
- What is the long-run relationship between direct and indirect real infrastructure i.e. are investors able to achieve long-term portfolio diversification benefits by allocating funds to both direct and securitized infrastructure?
- Are indirect and direct infrastructure assets driven in the long run by the same underlying business factor - namely infrastructure?
- Are there similarities regarding the long-run relationship between direct and indirect real estate and direct and indirect infrastructure and are there any links between infrastructure and real estate returns over the long run?
- What are the adjustment speeds between direct and indirect infrastructure and the long-run equilibrium?
- What are the short-run dynamics between direct and indirect infrastructure and what are the theoretical and empirical implementations?
- Does indirect infrastructure reflect stock market or infrastructure performance in the short run?

Infrastructure - A New Dimension of Real Estate? An Asset Allocation Analysis

- What is an appropriate definition of infrastructure and what is the present status of research on infrastructure investment research and what is the future potential in an asset allocation context?
- What mechanisms and frameworks are necessary to further develop the infrastructure investment market?
- What data are currently available and to what extent do they limit infrastructure investment research?

- What are the risk, return and diversification characteristics of direct and indirect infrastructure assets compared to other main assets?
- What are the theoretical similarities and differences between real estate and infrastructure assets?
- What are the empirical similarities and differences between infrastructure and real estate and should both be regarded as unique and separate asset classes?
- Which role do direct and indirect infrastructure play in a multi-asset portfolio using a semi-variance optimization (Estrada, 2007) and different investor specific target rates of return?

Real Estate: A Victim of Infrastructure? Evidence from Conditional Asset Allocation

- What is the present state and scope of the literature in this relatively new field of investment research?
- What role does infrastructure play in a multi-asset portfolio when using a downside risk optimization (Bawa and Lindenberg, 1977) and a broad set of assets including traditional assets like stocks bonds and real estate as well as alternatives like private equity and commodities?
- What are the downside diversification benefits of infrastructure compared to other assets when a distinction is made between different market phases?
- What performance characteristics does infrastructure delivers during different phases of the general equity market and what are the effects on specific portfolio allocations?
- How does a situation of constrained asset weights affect the role of infrastructure in the portfolio?
- How does the allocation to infrastructure change under the assumption of different investor specific target rates?
- Infrastructure and real estate share some similar underlying characteristics, but is infrastructure able to replace real estate in the portfolio by delivering performance characteristics which are superior to those of real estate?

How much into Infrastructure? Evidence from Dynamic Asset Allocation

- What are the time-varying asset weights of infrastructure, when using an extending as well as a rolling optimization approach, which accounts for semi-variance as well as downside-risk?
- To what extent do these results differ from static optimization procedures?
- What are the long-term asset characteristics and diversification benefits of infrastructure compared to other assets?
- How does changing the investment horizon affect infrastructure allocations?
- How does the inclusion of infrastructure affect the risk (mean-variance and mean-downside risk) and return characteristics of a multi-asset portfolio over time?
- Is there a difference in portfolio weights if real as opposed to nominal asset returns are used for optimization?
- Does changing the target returns affect the allocation to infrastructure over the observation horizon?
- Does the inclusion of infrastructure specifically affect the allocation to real estate and is the allocation pattern of both assets similar over time?

Direct Infrastructure Investment and its Role in Drawdown-Efficient Portfolios

- To what extent is infrastructure allocated to the portfolio when the data frequency is on a monthly basis and the applied measure of risk is Conditional Drawdown at Risk (CDaR) according to Checkolov et al. (2000, 2003, 2005)
- What are the drawdown characteristics of infrastructure compared to other assets over time?
- What is the allocation to infrastructure if a dynamic optimization process is applied in this context?
- How does changing the confidence intervals affect allocations?
- Is Infrastructure a hedge against pension liabilities?
- How does the allocation towards infrastructure change if different investor specific target rates of return are applied?
- Can infrastructure hedge against downside systematic risk?

1.3 Course of Analysis

The following overview presents the chronology of the five articles, with regard to the authors (alphabetical), the publication history as well as the current publication status.

The Interactions Between Direct and Securitized Infrastructure and its Relationship to Real Estate

Authors: Konrad Finkenzeller, Benedikt Fleischmann

Submission to: Review of Quantitative Finance and Accounting

First Submission: 16/09/2011

Current Status: Under review

Infrastructure – A New Dimension of Real Estate? An Asset Allocation Analysis

Authors: Tobias Dechant, Konrad Finkenzeller, Wolfgang Schaefers

Submission to: Journal of Property Investment and Finance

First Submission: 16/12/2009

Acceptance for Publication: 30/03/2010

Current Status: Published Volume 28, Number 4, 2010

Real Estate: A Victim of Infrastructure? Evidence from Conditional Asset Allocation

Authors: Tobias Dechant, Konrad Finkenzeller, Wolfgang Schaefers

Submission to: Journal of Real Estate Portfolio Management

First Submission: 21/09/2011

Current Status: Under review

How much into Infrastructure? Evidence from Dynamic Asset Allocation

Authors: Tobias Dechant, Konrad Finkenzeller

Submission to: Journal of Property Research

First Submission: 02/08/2011

Revised Submission: 18/10/2011

Revised Submission: 09/01/2012

Current Status: Under review

Direct Infrastructure Investment and its Role in Drawdown-Efficient Portfolios

Authors: Tobias Dechant, Konrad Finkenzeller

Submission to: Journal of Banking and Finance

First Submission: 16/12/2011

Current Status: Under Review/with editor

2. The Interactions Between Direct and Securitized Infrastructure and its Relationship to Real Estate

Konrad Finkenzeller Benedikt Fleischmann

Abstract

The importance of infrastructure as an alternative asset has emerged significantly in recent years. Based on a novel dataset, this paper investigates the long-run relationships and short-run dynamics between direct and securitized infrastructure returns and the relationsship to the relevant real estate indices. Based on a cointegration analysis, we are able to detect the existence of a long-run relationship between direct and securitized infrastructure driven by a common underlying infrastructure business factor. This result implies that investors are not able to realize long-term portfolio diversification benefits by allocating funds to both direct and securitized infrastructure, since they are substitutable over the long run. However, in the short run indirect infrastructure is driven by the general stock market and follows the direct infrastructure market - a status (similar in particular to the "pre-Reit era"), which might reflect the lack of segmentation and focus of listed infrastructure companies. Furthermore, we are unable to investigate the relationship between direct infrastructure and direct real estate returns, either in the short run or long run - a result which contradicts to the assumption of infrastructure as being a subset of or substitute for real estate.

2.1 Introduction

During recent years, infrastructure investments[1] have become increasingly appealing for institutional investors such as pension funds and insurance companies.[2] Especially factors like infrastructures conservative nature, as a tangible and real asset, along with distinctive risk return characteristics (compared to conventional assets) account for it being classified as a viable alternative investment opportunity. However, despite the diversity in the infrastructure asset universe, investors have been attracted by the asset class for three main reasons. Firstly, institutional investors are seeking new sources of diversification to supplement core assets like stocks, bonds and real estate in order to avoid substantial losses as experienced during market downturns. Earlier studies measuring the diversification benefits of infrastructure, such as Newell and Peng (2009), Finkenzeller et al. (2010), Dechant et al. (2010) have provided evidence of such benefits. Secondly, the inelastic demand for and consequently stable and predictable cash flows of infrastructure investments match investors' future liabilities (Inderst 2010). Thirdly, infrastructure investments are considered as providing an (at least partial) hedge against inflation. However, this depends on the specific design of the asset, as well as the degree of regulation and pricing power (Bitsch et al. 2010).

Private investment opportunities in this sector are driven predominantly by a major imbalance between demand and supply. By 2030, global infrastructure requirements are estimated at being around US$ 3 trillion per annum, while financially constrained governments will only be able to provide about US$ 1 trillion (OECD 2006). The economic impact of this imbalance will be significant and further promote private involvement, along with private investment opportunities. The link between infrastructure investment, economic productivity and growth is well established in the macroeconomic literature (Röller and Waverman, 2001; Esfahani and Ramirez, 2003) and is generally accepted. The World Economic Forum recently highlighted underinvestment in infrastructure as one of three main global risks in the future (WEF 2010).

Private investment in infrastructure can be made either directly (unsecuritized) by acquiring the physical asset /the specific user rights[3] or via several forms of indirect (securitized) infrastructure, such as closed-ended funds (for example private equity funds, Axelson et al. 2007)

[1] Infrastructure assets can be divided into two main categories: economic and social infrastructure. Economic infrastructure includes long lasting, large-scale physical structures like transportation and communication infrastructure, as well as energy and utility facilities. Social infrastructure, on the other hand, includes education, healthcare, waste disposal as well as judicial facilities (Wagenvoort et al.2010)

[2] The US pension fund CalPERS, for example, intends to increase its infrastructure allocation from 0.5% to 1.5% within the next two years. Some Australian and Canadian pension funds already have an infrastructure share of over 10% (Inderst, 2009).

[3] Specific infrastructure sectors/projects are subject to specific pre-defined user rights with the government i.e. the private investors are not able to gain freehold interests on the assets. User rights entail private investors' duties and rights for a specific contract period, after which the user right returns to the government.representing the owner of the freehold right.

and listed infrastructure companies. Intuition suggests that the same fundamental market factors influence both securitized and unsecuritized infrastructure assets, although some major differences remain. Unsecuritized infrastructure assets face lot-size and illiquidity issues, immature market structures and lack effective secondary asset markets. Additionally, direct infrastructure markets are characterized by low information efficiency along with intransparent structures which in turn yields in (comparatively) high information and due-diligence costs, which significantly affect direct investment returns. Especially listed infrastructure can mitigate the specific disadvantages of direct infrastructure assets and has thus experienced a significant rise during the last few decades. Listed infrastructure shares/assets offer a high level of liquidity and transparency, also reducing the minimum required investment i.e. the market entrance barriers for potential investors. However, infrastructure share prices are only reflect the underlying fundamental (the infrastructure business) value, but also depended on factors like the state of the overall capital market, stock market sentiment as well as liquidity.

Both direct and securitized infrastructure assets are influenced by and represent the same underlying business, namely infrastructure. The relationship between the two is of considerable importance for asset allocation decisions and subsequently, the first focus of the paper is on providing an understanding of dynamic interactions and linkages between direct and listed infrastructure assets. The question of whether listed infrastructure actually provides exposure to direct infrastructure or merely represents additional exposure to common stocks, is fundamental to the analysis, with respect to both the short and long-run dynamics. Although the contemporaneous correlation between indirect and direct infrastructure returns is estimated as low (Dechant et al. 2010) and suggests potential gains from diversification, the existence of a long-run relationship between both assets may limit such diversification benefits, especially for long investment horizons. If listed and direct infrastructure are cointegrated with each other, both assets would be substitutable within a portfolio i.e. the long run diversification benefits of adding infrastructure to the portfolio would be similar for both indirect and direct infrastructure assets. This information is crucial for long-term buy and hold investors such as pension funds and contributes significantly to their long-term asset allocation decisions with regard to infrastructure. Furthermore, we also consider the effect of cointegration on the short-run dynamics between indirect and direct infrastructure and analyze whether one asset has predictive power for the other.

The second focus of the paper is on the relationship between infrastructure and the related real estate sector. Due to their apparently underlying similarities with similar investment vehicles, investors indentify with infrastructure mainly as assets that are related to/ or are a subset of commercial real estate and therefore often replace real estate with infrastructure assets in their portfolios. This study analyzes the rationality of such behavior and investigates the short-run dynamics and long-term interrelations between real estate and infrastructure assets. Indeed, despite the diversity of infrastructure assets, the similarities in underlying infrastructure asset characteristics and real estate assets are obvious. Among others, both asset classes share a physical and real-asset character, large investment lot sizes[4] which create high entry barriers, long-term investment horizons, stable and predictable cash-flow patterns during operating phases, income and capital-return components, a dependency of asset pricing on valuations, expected inflation-hedging characteristics and diversification potential with respect to traditional assets.[5]

Due to the underlying asset similarities, along with the existence of direct and securitized investment opportunities for both assets -infrastructure and real estate- the literature related to our research questions is sourced from the real estate sector. The interrelation and dynamics between direct and securitized real estate is a core question in real estate research and has been discussed in various academic studies. Research shows that the long–term linkages between indirect and direct real estate assets are indeed substantially stronger than assumed by the simple correlation figures (Oikarinen et al. 2011, Kluger 1998, Giliberto 1990). Indirect returns are estimated to lead direct real estate returns (Geltner and Kluger 1998, Pagliari et al. 2005), a result which is evident from the early 1990s[6] onwards. During this period, an informationally maturing REITs market began to reflect the true underlying real estate value more accurately, so that the differences between indirect and direct real estate returns began to diminish over time (Clayton MacKinnon 2001, Pagliari et al 2005). However, in the short run REITs are influenced by general stock market behavior and sentiment (Hoesli and Serrano 2007). These questions are similar to those associated with listed and direct infrastructure assets. Therefore, we adopt objects of study from the field of real estate research and apply them to infrastructure.

[4] Private infrastructure project finance (Esty, 2004, Gatti et al. 2007) is usually operated through a special purpose vehicle (SPV). Dependent on the maturity stage and/or the type and size of the infrastructure project, various different equity investors and debt lenders are involved. Although individual projects can be extremely large, the involvement of a variety of equity investors, along with high gearing ratios, could reduce the lot-size problem from an equity investor perspective. The median project deal size (debt plus equity) is estimated at about $200-300 million (Araujo 2010).

[5] However, despite the obvious similarities, the differences between both assets are striking. Whereas property markets can be described as relatively competitive, infrastructure markets often reveal oligopolistic or even monopolistic structures. A further issue is the limited potential to acquire ownership of direct infrastructure assets, due to regulatory constraints, which often only allow user rights. Moreover, real estate, in general, may lend itself to appropriate alternative uses, whereas infrastructure assets are limited to very specific and restricted uses. Furthermore, there is a greater degree of transparency in the real estate market, than in the infrastructure market.

[6] The so called "new REIT era" in the early 1990's is regarded as a point of segmentation and maturitisation of REITs and goes along with the tax reform act in 1993. An increasing number of institutional participants was able to facilitate information demand and flows in public markets (see, for example, Bradrinath 1995, Chiang, 2009, Glascock et. al. 2000).

We are able to detect a long-run relationship between direct and securitized infrastructure driven by an unquantifiable underlying infrastructure factor which stems from a common business model of both indices. Additionally, we find that in the short run, the direct infrastructure market leads the indirect market, a situation which is comparable with the pre-REIT era in the US (Meyer and Webb, 1994) and may reflect the immature and inefficient state of the infrastructure market. With regard to the related real estate sector, we are not able to detect short-run dynamics or long-term interactions between both asset classes.

The reminder of the paper is structured as follows. Section 2 describes the data and the methodology which is based on Johannsen and Engle Granger cointegration tests. The results are presented in Section 3. The final section draws conclusions and suggests areas for further research.

2.2 Data

The investigation employs US total return index data covering the period from Q2 1990 to Q2 2010. In particular, we consider direct and listed infrastructure, direct and listed real estate, stocks and bonds. Infrastructure and real estate data are selected in accordance with our research questions, whereas stocks and bonds represent the main assets classes.

The general stock market is represented by the S&P 500 Composite series. The bond market is represented by the Barclays US Treasury Bond 104 Index. Listed infrastructure is represented by the UBS US Infrastructure and utilities index, which is sourced from Bloomberg. At Q2 2010, the index consists of 88 infrastructure and utility companies listed in the US and has a total market capitalization of US$ 574 billion.

The direct infrastructure performance index is provided by the Center of Private Equity Research (CEPRES) and is a sub-index of a more general CEPRES dataset of private equity investments and which has been used by former studies including Franzoni et al. (2011), Krohmer et al. (2009), Füss and Schweizer (2011). The infrastructure index covers a 930 individual operating infrastructure project in the US and is based on a broad reporting sample of 135 global infrastructure equity investors. The index methodology is in accordance with Peng (2001) and is based on the Method of Moment Repeat Sales Regression (MM-RSR). In Peng's original approach to determining a venture capital index, his dataset is based on financing rounds of various venture capital firms[7]. The initial financing round at time t_0 is employed to determine the actual price P_0 of the investment project. With the next financing round at t_1, the new value P_1 of the investment is established. This process continues through

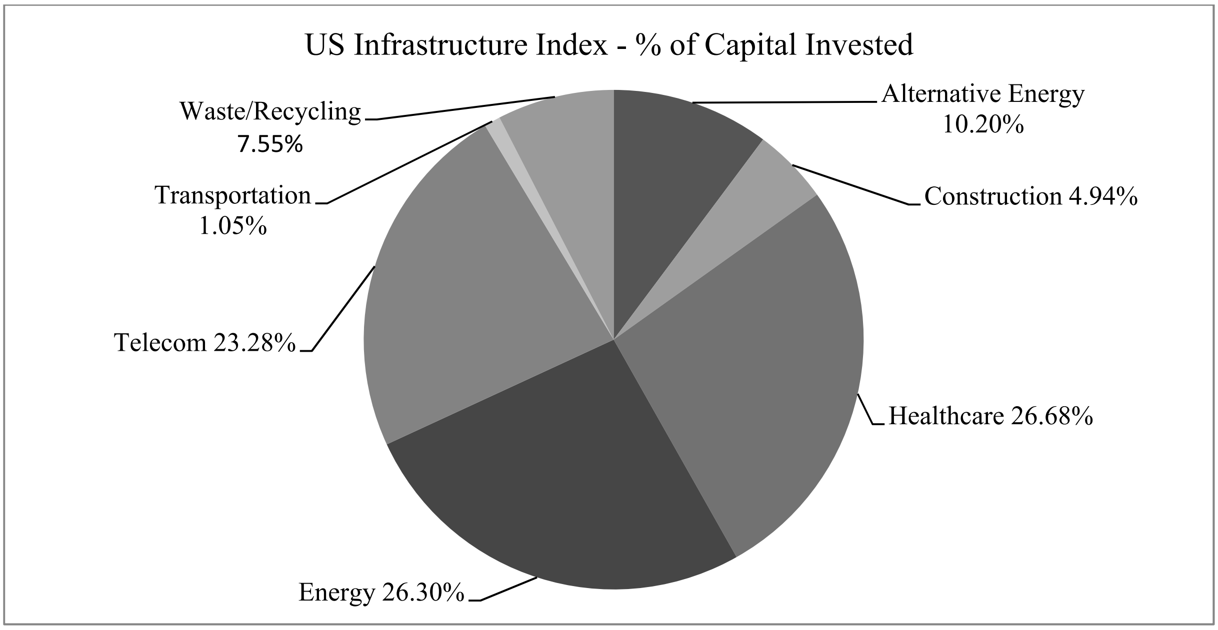
[7] Financial rounds could refer to the initial financial rounds, follow-on investments, IPOs, amortization or write- offs.

each financing round. An issue with the CEPRES data is that the base data does not consist of financing rounds, but is derived from cash flows, and the matching financing rounds are unknown. Therefore, prices are estimated by using the cash flows (net) themselves. With these estimated prices, one can proceed with the methodology proposed by Peng (2001). In order to estimate the prices of investments using cash-flows, the IRR from each cash flow is determined. The initial cash flow in t_0 constitutes P_0. By using the IRR of the cash flow series, P_0 is compounded until the next cash flow. This results in an estimation of the value P_1, which corresponds to the interest gained at time t_1. Adding the costs (or subtracting the gains) for the interests acquired (or sold) at time t_1.to the actual value acquired at t_1, yields in the total worth of the interests held. [8] For a more formal illustration of this process, refer to Schmidt and Ott (2006).

To aid comparison with unlevered real estate data and to demonstrate unbiased direct infrastructure performance, the index is corrected for gearing. The capitalization of the index adds up to around $27.2 billion of invested equity and only includes sectors in accordance with the definition of infrastructure from Kaserer et al. (2009). The relatively high weights of health care, energy and telecom assets are in accordance with the investment objectives of various types of investors and reflect the weights of institutional infrastructure investments. Together with a sufficient number of transactions and a high market capitalization, the index constitutes an appropriate tool for benchmarking direct infrastructure performance in the US. Exhibit 1 shows the average sector weights, which are calculated according to capital invested over the entire sample period. The average index shares are 34% for social (health care, waste/recycling) and 66% for economic (transportation, telecom, energy, alternative energy, construction) infrastructure.

[8] When the subsequent values of the initial cash are not all positive, the original cash flow series is divided into smaller series.

Exhibit 1: US Infrastructure Index Sector Weights



The TBI Index, which is published by the MIT center for Real Estate, is applied to reflect direct real estate performance. The index is based on the NCREIF index portfolio and reflects transaction-based performance i.e. it is not subject to lagging and smoothing effects (Geltner 1993). All remaining assets are derived from Thomson Datastream. We use the FTSE NAREIT Equity Index to mirror the American real estate stock market.

The main differences between both pairs (infrastructure and real estate) of listed and direct indices are twofold. Whereas both listed indices are subject to leverage, which affects the mean and amplitude of asset returns, both direct return series are in an unlevered status. Moreover, the sector mix in both index pairs differs from one another, an issue which has been discussed in the real estate literature (Pagliari and Webb 1995, Pagliari et al 2005). However, these issues could effect the short-run link, but not the long-run relationship between asset returns i.e. the presence of a common underlying "real estate" or "infrastructure" factor, which drives both indirect as well as direct asset returns. The underlying factor is not quantifiable, but represents the underlying common business activity of both related return series.

Contrary to trading most financial assets, buying and selling direct real estate and direct infrastructure evokes high transaction costs, which reduce returns. Round trip costs of 6%[9] are employed for US real estate transactions. Infrastructure transactions costs are, to a large extent, independent of the size of the project, since they all require general services such as technical, legal and financial advisory, as well as a sound estimation of demand risk. As a

[9] We thank David Geltner for providing this information.

result, the cost can amount to a maximum of 10% of total project cost. Average infrastructure projects evoke round trip costs of about 7.5%[10] (for road projects, see for example Dudkin and Välilä, 2005, Salino and de Santos, 2008). However, actual transaction costs depend on the holding period of assets. Based on the findings of Fisher and Young (2000) and Geltner and Pollakowski (2007), the average institutional holding period of direct real estate is roughly ten years. According to Kaserer et al. (2009), the average duration of infrastructure investments is four years, which seems very short. However, there is a huge difference between the average concession period which is agreed between the government and the SPV, and the holding period of an individual equity investor. While concession periods agreed between the regulator and the SPV are around 30 years across all sectors, on average, an individual investor might have shorter holding periods, depending on strategic issues, such as the stage of the infrastructure project (OECD, 2010). Due to the growing maturity of the market and the increasing involvement of long-term investors, the average holding is likely to rise over the next few years. We use this information from Geltner and Pollakowski (2007) and from Kaserer (2009) to adjust direct real estate and direct infrastructure returns.

2.2.1 Correlations

Exhibit 2: Inter-Asset Correlations Based on Annual Returns

	Inter Govt. Bonds	S&P 500 Stocks	Direct Infrastructure	Indirect Infrastructure	Direct Real Estate	Indirect Real Estate
Inter Govt. Bonds	1					
S&P 500 Stocks	-0.23	1				
Direct Infrastructure	0.02	-0.02	1			
Indirect Infrastructure	0.08	0.52	-0.01	1		
Direct Real Estate	-0.10	0.17	0.08	0.18	1	
Indirect Real Estate	-0.08	0.61	-0.03	0.48	0.28	1

Inter-asset correlations are presented in Exhibit 2. The results demonstrate the good diversification benefits of direct infrastructure by providing negative correlations with indirect real estate (-0.03), indirect infrastructure (-0.01) and stocks (-0.02). The correlations for the remaining assets, like direct real estate (0.08) and government bonds (0.02) are only moderately positive. With figures of 0.52 for stocks and 0.48 for indirect real estate, indirect infrastructure yields high correlations with its listed counterparts. However, the correlations also mirror the good diversification benefits of direct real estate, with negative figures of -0.10 for government bonds and moderately positive correlations for all other assets, ranging between 0.08 for direct infrastructure and 0.28 for indirect real estate. Similar to indirect infrastructure, in-

[10] We thank various institutional infrastructure investors and consultants for providing this information.

direct real estate is correlated with stocks (0.61) and indirect infrastructure (0.28), but exhibits, in contrast to indirect infrastructure, a positive correlation with its underlying direct real estate performance (0.28).

2.3 Methodology

In order to determine the role and relationship of infrastructure investments, we test for long-run co-movements, as well as short-run dynamics with respect to other time series, because simple correlations on quarterly frequency can lead to misleading interpretations of portfolio diversification effects. Although the time series of returns can be zero (highly) correlated in the short run, they can exhibit strong (weak) long-term relationship(s) and this in turn, should lead to diminishing (increasing) diversification effect between assets (Pengpis and Swanson 2010).

Our first step is to perform a battery of unit roots tests to reach the prerequisite of cointegration, i.e. the time series contain a unit root and are integrated of the same order. We perform the three different unit root tests with various benefits. The Dickey-Fuller Generalized Least Squares (DF-GLS) test (Elliot et al. 1996), the Zivot-Andrews (ZA) test (Zivot and Andrews 1992) and the Kwaitkowski, Phillips, Schmidt and Shin (KPSS) test (Kwaitkowski et al. 1992). The DF-GLS test dominates the ordinary Dickey-Fuller, in terms of small-sample size and power (Maddala and Kim 1998). The ZA test allows for a structural break at an unknown time. While DF-GLS and ZA test have the null hypothesis of non-stationary the KPSS test controls for the converse. Thus, the latter test is for robustness, since it investigates whether the time series is fractionally integrated (that is neither $I(0)$ nor $I(1)$). All unit root tests are performed including a constant and thus allowing for a break in the intercept for the ZA test. Exhibit 3 shows that the null hypothesis of a unit root is not rejected for levels, and clearly rejected for the first differences at a 1 percent significance level for the DF-GLS and ZA tests. The KPSS test rejects the stationarity of the levels and indicates the stationarity of the first differences (except the direct real estate returns at a 10 percent level). Hence, all examined time series should be $I(1)$.

Exhibit 3. Unit Root Test

	Log Levels				Log First Differences			
	ADF	DF-GLS	ZA	KPSS	ADF	DF-GLS	ZA	KPSS
Direct Infrastructure	-2.077	0.58	-3.174	1.553***	-8.062***	-2.214**	-10.904***	0.028
Indirect Infrastructure	-1.499	0.124	-3.344	0.444***	-5.058***	-2.628***	-7.897***	0.049
Direct Real Estate	-0.395	0.471	-3.664	0.444***	-4.202***	-2.606***	-9.27***	0.201*
Indirect Real Estate	-1.189	0.226	-4.214	0.309***	-5.991***	-2.886***	-8.251***	0.054
S&P 500 Stocks	-1.817	-0.046	-2.701	1.449***	-5.119***	-3.089***	-8.623***	0.078

In the second step, we test the pair-wise co-movement of two time series by using the Engle and Granger (1987) procedure and the Johansen (1988) / Johansen and Juselius (1990) methodology, and test for the null hypothesis of no co-integration. According to Engle and Granger, two non-stationary time series are regressed on each other by simple OLS:

$$X_{i,t} = \alpha + \beta X_{j,t} + \varepsilon_t \qquad (1)$$

and the residuals ε_t are tested for stationarity by ADF and by using the MacKinnon (1991) critical values. The two time series are co-integrated, if they are both $I(1)$, which we tested above and their residuals from (1) are stationary. The results are summarized in Exhibit 3.
The procedure of Johansen and Juselius links vector auto regression (*VAR*) with cointegration. A *VAR(k),* which is defined as:

$$X_t = \mu + A_1 X_{t-1} + A_2 X_{t-2} + \ldots + A_k X_{t-k} + \varepsilon_t \; A_i \qquad (2)$$

where k is the lag length, A_i are the coefficient matrices, X_t is the *n*-dimensional vector of price levels or the levels of the state variables respectively at time t, and μ is a vector of constants. If two or more time series are cointegrated (share a long-run relationship), the *VAR (k)* can be written as a vector error correction model (*VECM*):

$$\Delta X_t = \mu + \Pi X_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta X_{t-i} + \varepsilon_t \qquad (3)$$

where ΔX_t is the vector of first differences respectively the asset returns as above. The matrices Γ_i represent short-term dynamics, whereas Π represents long-run relationships. If Π has a full rank n, no cointegration relationship is present. If Π has a rank $0 < r < n$ then r cointegration relations do exist. Here, Π can be decomposed into:

$$\Pi = \boldsymbol{\alpha\beta}'$$

where $\boldsymbol{\alpha}$ is the matrix with the adjustment speeds towards the long-run equilibrium and $\boldsymbol{\beta}'$ describes the r cointegrating relationships. To determine the number r of cointegration relationships, we rely on the maximum-eigenvalue and the trace test with the test statistics:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{k} \ln(1-\lambda_i)$$

$$\lambda_{\max-eigen} = -T \ln(1-\lambda_i)$$

where λ_i are the estimated eigenvalues of matrix Π. The test starts at $r = 0$ and investigates the number of eigenvalues significantly different from zero i.e. the number of cointegration relationships which could not be rejected.

In order to measure the short run dynamics, Granger Causality tests (1969a see lütkepohl) are applied. The test is based on the described *VAR* system. The approach tests whether the information of a lagged variable X_{t-1} has no information content to describe another variable Y_t. The causality is tested with a simple F-test and can provide some information with respect to lead-lag structures among the assets.

2.4 Results

2.4.1 Long-Run Dynamics

The diversification potential of assets generally entails two aspects, short-term correlation structures and long term co-movement. Correlation analysis is based a on specific frequency of observations (for example quarterly or annually) and may lead to miss-specified long term investment allocations. For this reason, we use cointegration technique to analyze long-term asset co-movements.

The findings of the Engel and Granger and Johansen cointegration tests for long run relationships are presented in Exhibits 4 and 5.

Exhibit 4: Engle-Granger Test

Indices		**Unit Root Test in Residuals**	
Endogenous Variable	Exogenous Variable	ADF	lag length
Direct Infrastructure	Indirect Infrastructure	-2.907**	1
Indirect Infrastructure	Direct Infrastructure	-2.609*	1
Direct Real Estate	Indirect Real Estate	-3.126**	1
Indirect Real Estate	Direct Real Estate	-2.884*	1
Direct Infrastructure	Direct Real Estate	-2.292	1
Direct Real Estate	Direct Infrastructure	-2.423	1
Indirect Infrastructure	Indirect Real Estate	-2.042	1
Indirect Real Estate	Indirect Infrastructure	-2.175	1
Indirect Infrastructure	S&P 500 Stocks	-1.961	1
S&P 500 Stocks	Indirect Infrastructure	-1.916	1
Indirect Real Estate	S&P 500 Stocks	-1.461	1
S&P 500 Stocks	Indirect Real Estate	-1.183	1

Note. The ADF test is employed with the MacKinnon (1991) ciritical values, lag length is selected with the AIC. ***,** and * indicate the rejection of the null hypothesis at a 1%, 5% and 10% significance level.

Exhibit 5: Johansen and Juselius Test for Cointegration Rank

Tested Pairs	H_0	**Eigen-value**	**Trace Test Statistic**	**Maximum Eigenvalue Test Statistic**
Direct Infrastructure	r=0	0.185	17.836**	17.602**
Indirect Infrastructure	r>=1	0.003	0.234	0.234
Direct Real Estate	r=0	0.204	18.947**	18.207**
Indirect Real Estate	r>=1	0.009	0.740	0.740
Direct Infrastructure	r=0	0.098	9.692	8.259
Direct Real Estate	r>=1	0.018	1.433	1.433
Indirect Infrastructure	r=0	0.099	10.839	8.347
Indirect Real Estate	r>=1	0.031	2.493	2.493
Indirect Infrastructure	r=0	0.067	8.618	5.607
S&P 500 Stocks	r>=1	0.036	3.011	3.011
Indirect Real Estate	r=0	0.044	5.278	3.601
S&P 500 Stocks	r>=1	0.021	1.677	1.677

Note. ***,** and * indicate the rejection of the null hypothesis at 1%, 5% and 10% significance levels. The critical values are reported in Table 9.

Exhibit 6: Normalized Cointegration Vectors

Direct Infrastructure	**Constant**	**Indirect Infrastructure**
1	0.365	-1.261***
		(-0.135)

Direct Real Estate	**Constant**	**Indirect Real Estate**
1	0.219	-0.847***
		(-0.049)

Note. ***,** and * indicate the rejection of the null hypothesis at 1%, 5% and 10% significance levels.

We provide new findings about infrastructure assets and are furthermore able to support and confirm some previous findings in the literature. Infrastructure and real estate exhibit similar behavior in terms of long-term relationships between their listed performance and their direct counterpart. Both pairs (real estate and infrastructure) reveal a significant link over the long-run at a 5 percent level for the Engel Granger test. The Johansen test rejects the hypothesis r=0 for both assets at a five percent level, so that the hypothesis r>=1 cannot be rejected. The used critical values can be found in Exhibit 9 in the appendix. The Johannsen procedure supports the results from the Engle Granger tests i.e. proves a cointegration relation between direct and indirect assets in each case. However, it is important to note that REITs are forced by law to remain within the core real estate business[11], but the listed infrastructure index is only a specialized sector-specific stock index with no binding investment rules and limitations, and is limited only with respect to the definition of infrastructure or to the index classification. Nevertheless, infrastructure characteristics seem to be present in the listed infrastructure index for the long run i.e. a common underlying, but not quantifiable infrastructure factor seems to influence both indices. This underlying factor can be explained theoretically by a common business activity of both infrastructure series (indices) and therefore, an exposure to similar cash-flow and risk patterns. The argument holds, despite the fact that the infrastructure mix of the UBS index differs from that of the CEPRES Index. This result corresponds with the findings from the real estate literature, namely the existence of a common long-term “real estate” factor in both indices (listed and direct), which is independent of the sector-specific breakdown of the index (see Oikarinen et al.2010, Pagliari et al. 2005).

The real estate findings are in accordance with the literature, whereas direct real estate performance is mostly represented by the NCREIF index, instead of the transaction-based TBI. However, the difference between the lagged appraisal-based NCREIF and the TBI should not matter for long-run cointegration relations (see Oikarinen et al. 2011).[12] Both results underpin the theory that indirect assets are driven by sentiment and noise in the short run, but in the long run, the prices of indirect assets float around their fundamental values. These fundamental values are based on current and future cash flows of the underlying business models i.e. infrastructure and real estate.

A relationship between real estate and infrastructure may be indicative of the fact that both assets share similar underlying characteristics (see Dechant et al. 2010). However, both cointegration tests reject this theoretical hypothesis, by yielding insignificant values for the listed

[11] US Internal Revenue Code:Sec. 856.

[12] For reasons of robustness, we also performed the analysis by using the NCREIF direct real estate index. The results obtained are similar to those of the TBI index in terms of estimated parameters and significance.

assets as well as for their direct counterparts. Since, in consequence, an interrelationship between both assets cannot be confirmed in the long run, it is rational to include both assets in a portfolio aiming at long-term investment horizons.

As indicated in Exhibit 1, all listed assets exhibit high positive correlations with the main stock market (0.49 for infrastructure and 0.65 for real estate) and are caused by short-term stock market sentiment. However, our cointegration tests do not support a significant long-run interrelationship between our listed real assets and the main stock market.

For more insight into the two significant cointegration relations, see equastions (5) and (6). The cointegration equations are normalized on the direct assets. The results indicate that direct and indirect infrastructure move in the same direction, whereas direct infrastructure is estimated to move with a factor of 1.261 with indirect infrastructure. In the same way, direct and indirect real estate moves with a factor weight of 0.847.

$$\text{Direct Infrastructure} = -0.365 + 1.261 \text{ Indirect Infrastructure} \tag{5}$$

$$\text{Direct Real Estate} = -0.219 + 0.847 \text{ Indirect Real Estate} \tag{6}$$

Exhibit 7: Adjustment Speed Coefficients

Direct Infrastructure	Indirect Infrastructure
-0.003	0.132***
(-0.011)	(-0.046)
Direct Real Estate	**Indirect Real Estate**
-0.075***	0.146**
(-0.026)	(-0.071)

Note. ***,** and * indicate the rejection of the null hypothesis at a 1%, 5% and 10% significance level.

Exhibit 7 represents the adjustment speed coefficients between the assets and the long-run equilibrium. The results indicate a strong and significant adjustment of indirect infrastructure towards the equilibrium. By contrast, this effect is not present for direct infrastructure returns. The real estate analysis shows that direct, as well as indirect returns, adjust significantly towards the equilibrium, whereas the adjustment speed for REITs is double that of direct real estate, represented by a factor of 0.146 respectively 0.075. This might indicate that direct infrastructure leads the indirect infrastructure market. On the other hand, real estate markets yield a more converse interaction between listed and direct assets.

2.4.2 Short-Run Dynamics

After investigating the existence of long-run relationships, the short run asset dynamics are investigated by Granger causality tests. The results are presented in Exhibit 8.

Exhibit 8: Granger Causality Test

Indicies			
Endogenous Variable	**Exogenous Variable**	**F-Test**	**VAR lag length**
Direct Infrastructure	Indirect Infrastructure	0.207	2
Indirect Infrastructure	Direct Infrastructure	4.247**	2
Direct Real Estate	Indirect Real Estate	12.263***	2
Indirect Real Estate	Direct Real Estate	1.818	2
Direct Infrastructure	Direct Real Estate	1.489	1
Direct Real Estate	Direct Infrastructure	2.065	1
Indirect Infrastructure	Indirect Real Estate	2.596	1
Indirect Real Estate	Indirect Infrastructure	0.098	1
Indirect Infrastructure	S&P 500 Stocks	5.462**	1
S&P 500 Stocks	Indirect Infrastructure	1.572	1
Indirect Real Estate	S&P 500 Stocks	0.575	1
S&P 500 Stocks	Indirect Real Estate	0.06	1

Note. ***,** and * indicate the rejection of the null hypothesis at 1%, 5% and 10% significance levels.

As shown over the long run, underlying fundamentals seem to be predominant in direct and listed assets. However, the short-run analysis sheds a different light on the relationship between listed infrastructure and its direct performance counterpart. We find a short-term influence of direct infrastructure, which is significant at a 5 percent level. Therefore, in the short run, direct market returns might be a better indicator of the infrastructure market factor. The dynamics for the real estate markets seem to be different. REITs lead future direct real estate returns significant at a 1 percent level, which is in accordance with recent findings on the "new REIT era" after 1993[13]. However, prior to this era, REIT markets had been regarded as immature and linked more to general stock markets and additionally, the direct market had predictive power for the listed market (Oikarinen 2010). We found a very similar situation for both aspects in infrastructure markets, because additionally to the perverse lead lag relation, we also found a significant influence of the general stock market on listed infrastructure returns in the short term. This might be caused by the fact that infrastructure markets are immature and listed companies are not forced by law to their specific business model even regarding the extent. However, we did not find a significant influence of general stock markets on indirect real estate (see for example Hoesli and Serrano, 2007). This observation might be

[13] The so called "new REIT era" in the early 1990's is regarded as a point of segmentation and maturitisation of REITs and is associated with the tax reform act of 1993. An increasing number of institutional participants was able to facilitate information demand and flows in public markets (see for example, Bradrinath 1995, Chiang, 2009, Glascock et. al.2000).

caused by the quarterly data frequency, which ignores the more rapid inter-quarterly effects between stocks and REITs. High correlations between both assets (0.61) support this argument. Furthermore, we are not able to support significant influences between direct real estate and direct infrastructure, which indicates the independency of both assets even in the short run.

2.5 Summary and Conclusions

Instigated by the attractive investment characteristics associated with infrastructure assets, institutional investor interest in and demand for private infrastructure investments has risen significantly during recent years. However, due to a lack of (direct) infrastructure performance data, academic research lags behind this development. Using a unique infrastructure dataset, we extend the existing literature on infrastructures portfolio benefits, by examining the short-run and long-run dynamic relationships and interactions between securitized and direct infrastructure returns, as well as their relation to the associated real estate sector. Our results contribute to the general understanding of direct and listed infrastructure asset returns and their relation to each other and in consequence, yield some important insights for actual asset allocation decisions.

Our results support a long run cointegration relationship between direct and indirect infrastructure return indices. Consequently, we detect similar behavior for infrastructure assets to that between direct and indirect real estate assets. This contradicts the intuition based on the short term inter-asset correlation between direct and indirect infrastructure returns which indicates no link between both assets. Thus, indirect infrastructure seems to reflect direct infrastructure performance in the long run i.e. a common unobservable underlying "infrastructure factor" seems to drive both indices. More precisely, indirect and direct infrastructure assets would be substitutes in an asset allocation context, if an investor's investment horizon is long. Therefore, asset allocation models which are based on correlations and extended to long horizons, could imply diversification benefits which are not present. Driven by similar underlying asset characteristics, practically-oriented investors often do not distinguish meaningfully between infrastructure and real estate investments in their portfolio. However, we are not able to support long-term relationships between infrastructure and real estate assets, whereas the indirect assets do reveal a high correlation. As a result, the two asset classes are not substitutable, have diversification benefits to each other in the long run and could, therefore, theoretically coexist in the same portfolio.

Our results for short run dynamics reveal an influence of direct on indirect infrastructure returns, a result which is not intuitive from an efficient market perspective. However, this result might be caused by the still immature infrastructure market structures, a situation which was also observable in the earlier US real estate market (pre "new REIT era"). We further find a significant short-term influence of general stock markets on listed infrastructure. This might be caused by an unregulated operational focus of infrastructure companies. In contrast to REIT's, they are not forced to invest in infrastructure to a specified extent.

Further research could focus on long term asset allocation scenarios, which take into account infrastructure as an additional asset. Moreover, especially the inflation hedging characteristics associated with infrastructure assets are important to long term investors.

2.6 Appendix

Exhibit 9: Critical Values for the Johansen and Juselius test

		Critical Values		
		10%	**5%**	**1%**
Trace Test	r=0	13.429	15.495	19.937
	r>=1	2.706	3.841	6.635
Maximum Eigen-value Test	r=0	12.297	14.265	18.520
	r>=1	2.706	3.841	6.635

2.5 Literature

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3. Infrastructure - A New Dimension of Real Estate? An Asset Allocation Analysis

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Abstract

Purpose: The purpose of this paper is to provide conclusive evidence that infrastructure constitutes a separate asset class and cannot be classified as real estate from an investment point of view. Furthermore, we determine optimal allocations for direct and indirect infrastructure within a multi-asset portfolio.

Design/Methodology/Approach: We optimize portfolio allocations by using an algorithm which accounts for downside risk rather than variance. This approach is more in accordance with the actual investor behaviour and might meet their investment objectives more effectively. An Australian dataset comprising stocks, bonds, direct real estate, direct infrastructure and indirect infrastructure is applied for portfolio construction.

Findings: Although infrastructure and real estate have common characteristics, we arrive at the conclusion that they constitute two different asset classes. Furthermore, we highlight the diversification benefits of direct and indirect infrastructure within multi-asset portfolios and determine efficient allocations up to 78% for target rates of 0.0%, 1.5% and 3.0% quarterly.

Practical Implications: The results will help investors and portfolio managers to efficiently allocate funds to various asset classes. Most institutional investors are not familiar with investments in infrastructure. This study facilitates a better understanding of the asset class *infrastructure* and yields some important implications for the optimal allocation of infrastructure within institutional investment portfolios.

Originality/Value: This is the first study to examine the role of direct and indirect infrastructure within a multi-asset portfolio by applying a downside-risk approach.

3.1 Introduction

The economic importance of infrastructure has been the subject of extensive research since the late 1980s and is free of controversy. The World Economic Forum (2008) lists infrastructure as one of the most crucial elements to a country's productivity and competitiveness. Aschauer (1989) provides evidence of significant links between investment in infrastructure and a country's economic development and wealth. Yeaple and Golub (2004) suggest that infrastructure is one of the key determinants of a region's comparative advantage. Though infrastructure is recognized as a crucial input for economic productivity, there is no clear and unanimous definition of the term. An early definition is given by Stohler (1964), who characterizes infrastructure as the substructure or the "skeleton" assets of an economy that are essential for the production of goods and services. Later approaches have subdivided infrastructure into social and economic subgroups. Economic infrastructure (including transport, energy/utilities and communication facilities) provides key services to business and industry and enhances productivity and innovation. Social infrastructure, on the other hand, is seen as a medium for supplying basic services to households (healthcare, education and judicial facilities) (ING, 2006). In recent years, private investments in infrastructure have increased significantly and investors have begun to perceive infrastructure as an attractive asset class enhancing the efficiency of their investment portfolios. Financial strain on governments, making them unable to provide adequate infrastructure provision in times of increasing global competitiveness has contributed to the emergence of private investment opportunities in recent years (RREEF, 2006). A shortage of good quality commercial real estate, along with declining yields, has intensified this development and amplified the capital flow into seemingly related sectors (Newell and Peng 2008). Although many investors are restraining their investments due to the current financial crisis, infrastructure still seems to be very attractive, a fact which is underpinned by the INREV[14] Investment Intentions Survey 2009: According to this study, more than 60% of all institutional real estate investors considered allocating funds to the infrastructure sector in 2009.

Since infrastructure and real estate exhibit many common characteristics, this paper aims at contributing to the debate on whether infrastructure can be regarded as real estate or constitutes a separate asset class. Furthermore, we provide an asset allocation model which determines optimal infrastructure asset allocations for a downside risk (DR) – averse investor. This optimization technique is based on Estrada (2008) and considers target semivariance instead

[14] European Association for Investors in Non-listed Real Estate Vehicles.

of variance as measure of risk. This might more effectively meet the investment objectives of rational investors and result in more realistic asset allocations for a set of Australian data. The remainder of this paper is structured as follows. Part two presents the applied data, and section three analyses the differences between infrastructure and real estate. This is followed by a review of the downside risk concept and its application to portfolio structuring. The study is completed with some conclusions and an outlook for future research.

3.2 Applied Data

The Australian infrastructure market is relatively mature and time series data on infrastructure returns (direct and indirect) are available. For that reason, this market is in the focus of this analysis.

During the past decade, definitions of infrastructure have broadened and sometimes encompass categories that can barely be linked to one another (Beeferman, 2008): There are opposing views on the issue of whether utilities can be regarded as infrastructure or not (Inderst 2009). Researchers and practitioners generally do not draw any accurate distinction between them, but use the term "infrastructure" interchangeably. Estimating the correlations between quarterly (1994:4 to 2009:1) indirect infrastructure (UBS Australia Infrastructure Index) and indirect utilities (UBS Australia Utilities Index) returns, reveals a coefficient of correlation of 0.35 which is significant at a 5%-level. As a result, we adhere to this common definition and use the UBS Australia Infrastructure *and* Utilities Index to mirror the performance of indirect infrastructure.[15]

Time series total return data on direct and indirect infrastructure performance are provided by Bloomberg and Colonial First State, respectively. Return data on equities, bonds and direct property are from Thomson Datastream and IPD (Investment Property Databank). All time series range from Q4 1994 to Q1 2009, which is sufficient to cover at least one entire market cycle. The UBS Australia Infrastructure & Utility Index depicts the performance of indirect infrastructure. An index constructed by Colonial First State measures direct infrastructure performance. This index is an equally weighted total return index comprising five Australian infrastructure funds, and is based on valuations and therefore subject to smoothing. This implies a downward bias in the second central moment of the return distribution, since appraisers take into account current as well as historic information to perform valuations. In order to

[15] Although this index covers infrastructure and utility performance, we refer to the expression "infrastructure" in the course of this paper

address this issue and remove the smoothing effect, the methodology of Geltner and Miller (1993) is applied. This serves to identify the underlying volatility of the infrastructure market and yields a greater comparability between appraisal-based returns and transaction-based equity and bond returns. Furthermore, the gearing level of 60%[16] was removed. Since the IPD Australian Property Index is also exposed to smoothing, the desmoothing procedure has to be applied as well. The Australian Securities Exchange index (ASX 100) is used to mirror equity performance, whereas the JP Morgan Australia Government Bond index depicts the performance of Australian Government Bonds.

Exhibit 1: Descriptive Statistics for Asset Returns

	Bond	Property	Direct Infra+Util	ASX	Indirect Infra + Util
Mean	2.02	2.36	2.00	1.93	3.69
Median	2.05	2.63	1.90	3.68	4.52
Standard Deviation	2.47	2.57	1.89	7.50	8.31
Sample Variance	6.11	6.60	3.58	56.18	68.98
Kurtosis	0.42	4.19	-1.10	7.85	1.93
Skewness	0.38	-1.59	0.13	-2.39	-0.39
Range	11.86	13.68	6.81	43.92	50.84
Minimum	-2.97	-5.95	-1.22	-31.87	-22.90
Maximum	8.89	7.73	5.59	12.06	27.94
Observations	57	57	57	57	57

The indirect infrastructure index offers the greatest average return, but is also subject to the highest standard deviation. The return from the unsmoothed and unlevered direct infrastructure index is lower than that of property and bonds. The poor performance of equities is due to the substantial withdrawal of funds in the course of the financial crisis.

3.3 Why Infrastructure is not Real Estate

There is a lively debate on whether infrastructure can be regarded as real estate or whether it constitutes a separate asset class with unique characteristics (Beeferman, 2008; Newell and Peng 2007; RREEF, 2005; Blundell, 2006). The typical characteristics which are common to all direct infrastructure investments can be subdivided into three groups of criteria: technical, institutional and economic. Technical characteristics include indivisibility, long life cycles and the site dependency of assets (Meeder, 2000). The main institutional criterion is a given level of decision-making competence of the public authorities in terms of allocation and regulation (Backhaus and Wertschulte, 2003). Long-term investment horizons, together with re-

[16] According to information provided by Mercer Although this index covers infrastructure and utility performance, we refer to the expression "infrastructure" in the course of this paper

stricted liquidity due to a very limited secondary market, can be classified as two of the main economic criteria (RREEF, 2007; Erlendson, 2006). Furthermore, infrastructure has inherent monopoly characteristics and provides essential economic and social services (Mercer, 2005; Erlendson, 2006). Stable, and therefore, predictable cash flows associated with potential capital gains allow for high levels of financial leverage (compared to other asset classes) (Beferman, 2008; Colonial First State, 2009; RREEF, 2005). Furthermore, large investment lot sizes create high barriers of entry. This, in turn, yields a market environment with professional actors who have high levels of market expertise (RREEF, 2007). Moreover, compared to other markets, the infrastructure market can be described as intransparent, due to a shortage of quality data and research (Inderst, 2009). The pricing of direct infrastructure projects is based on valuations (Newell and Peng, 2008), and underlying cash flows are intended to provide a hedge against inflation (ING, 2006). Due to its monopolistic character, there may be a lack of market prices (Backhaus and Werschulte, 2003). Erlendson (2006,) further states that infrastructure has (at least in the short run) a low elasticity of demand, since the construction of new assets requires a considerable amount of time. A high level of individual expertise in legal and regulatory regimes is necessary to provide efficient asset management.

Although direct infrastructure and direct property have some characteristics in common (indivisibility, long life cycles and site dependency), long-term investment horizons, restricted liquidity, valuation-based performance, supposed inflation hedge, capital gains), there are also substantial differences. Whereas property markets can be described as relatively competitive, infrastructure markets, as mentioned, often have oligopolistic or even monopolistic structures. Moreover, there is a greater degree of transparency in the real estate market than in the infrastructure market. A further issue is the limited potential to obtain ownership of direct infrastructure assets, due to regulatory constraints, which often only allow user rights (Newell and Peng, 2008). Even though an investment in direct real estate is inhibited by large investment scales, this problem becomes even more serious when an investment in direct infrastructure is considered. This, in turn, decreases the diversification benefit when infrastructure is allocated to a(n) (multi) asset portfolio. Moreover, real estate, in general, may provide alternative appropriate uses, whereas infrastructure assets are limited to very specific and restricted uses.

Institutional investors also face this classification problem when allocating infrastructure to their portfolios. Therefore, infrastructure is often placed in existing allocations, namely private equity, real estate or fixed income, although the risk-return characteristics do not match

(PFG, 2007). However, especially over the last few years, infrastructure has begun to emerge as an independent asset class (Inderst, 2009; Newell and Peng, 2008) as confirmed by a number of investor surveys. According to Preqin and Inderst (2008), 47% of active investors have a separate infrastructure allocation, whereas 43% include it in their private equity portfolio and 10% in their real estate allocation. PFG's investor survey reveals figures of 47% for a separate infrastructure asset allocation, 37% for an allocation within the private equity portfolio and 15% for a real estate allocation. (PFG, 2007).

According to Newell and Peng (2008), Colonial First State (2006) and RREEF (2007), infrastructure is appropriate for portfolio diversification, since it delivers a moderate to low correlation with traditional asset classes. We find similar results for the Australian data which, in turn, yield further indications for the separation of real estate from infrastructure.

As Exhibit 2 shows, there is positive but insignificant (5%) correlation (0.20) between direct property and direct infrastructure returns from Q4 1994 to Q1 2009, which contradicts the claim that infrastructure can be regarded as a subclass of real estate. Moreover, the correlation is even lower (0.04), when the effects of the financial crisis (Q3 2007 to Q1 2009) are extracted. This indicates that the higher correlation in the period from Q4 1994 to Q1 2009 is due to extreme market downturns from which neither asset class could withdraw. There is a strong and significant relationship between the indirect infrastructure and the NAREIT index (0.54), which might be due to the fact that both indices contain listed companies affected by movements in the equity market. However, before the crisis, this correlation was lower (0.27) and significant at only a 10%-level. This indicates that both investments were perceived as only weakly related before the financial crisis. According to these results, one might expect a divergence in return behavior when the world economy recovers.

Exhibit 2: Correlations

1995 Q1 - 2009 Q1

	Bond	Property	Direct Infra+Util	ASX	Indirect Infra + Util	NAREIT
Bond	1.00	-0.21	-0.02	-0.39	0.27	-0.09
Property		1.00	0.20	0.64	0.38	0.70
Direct Infra+Util			1.00	0.27	0.29	0.17
ASX				1.00	0.36	0.54
Indirect Infra + Util					1.00	0.54
NAREIT						1.00

1995 Q1 - 2007 Q2

	Bond	Property	Direct Infra+Util	ASX	Indirect Infra + Util	NAREIT
Bond	1.00	-0.03	0.09	-0.18	0.45	0.11
Property		1.00	0.04	0.16	-0.03	0.07
Direct Infra+Util			1.00	0.05	0.22	-0.08
ASX				1.00	0.12	0.21
Indirect Infra + Util					1.00	0.27
NAREIT						1.00

These findings, as well as the different risk-return characteristics, constitute an indicator for distinguishing explicitly between infrastructure and real estate, although many physical characteristics are common to both.

3.4 Infrastructure Asset Allocation

3.4.1 Modern Portfolio Theory (MPT)

Modern portfolio theory still constitutes an important tool for ascertaining the optimal proportion of an asset within a mixed-asset portfolio and for determining "*efficient*" portfolios out of a set of possible and permitted ones. According to Markowitz (1952), a portfolio is efficient when it either delivers the minimum risk for a given level of expected return or achieves the highest level of return for a given amount of risk. Efficient portfolios are considered as dominant, implying that a rational investor would prefer an efficient portfolio to one that is not efficient. The set of these efficient portfolios form the efficient frontier and can be determined by a mean-variance analysis. However, modern portfolio theory is constrained by some serious theoretical weaknesses and practical complications:

MPT is not consistent with the concept of a minimum required return or target return, which, however, is usually applied by institutional investors (Sivitanides, 1998, Mao, 1970). This concept describes an investor's concern with failing to meet a minimum required level of return. A rational investor would only be apprehensive of returns below this aspiration level, whereas returns exceeding this target rate cannot be considered as risk, but rather as a riskless chance of obtaining unanticipated high returns (Sing and Ling, 2003). The mean-variance approach does not allow for a certain, investor-specific, target rate, but has an implicitly defined reference point, namely the mean. This number, however, might not be suitable for all investors and could contribute to portfolio allocations which are not appropriate for a particular investor. Moreover, the mean-variance model treats deviations from the mean – irrespective of whether they are above or below – in the same way, and both kinds of deviations are incorporated into the risk assessment of a certain asset (Sing and Ong, 2000). However, this theory does not adequately mirror the risk perceptions of rational investors and therefore simply ignores their investment objectives. Consequently, the application of MPT could result in flawed asset allocations. Furthermore, due to assumptions of normally and independently distributed returns, the application of the mean-variance methodology is limited when asset returns are skewed. In terms of utility theory, the underlying utility function is unable to take into account varying degrees of risk aversion. To overcome these drawbacks and to derive asset allocations which are more in accordance with the actual behaviour and preferences of investors, a portfolio optimization technique based on a downside risk measure is taken into account.

3.4.2 Mean Semivariance Optimization

According to Estrada (2007), the downside risk of an asset i can be described by its semivariance with respect to a benchmark B $(\Sigma_{iB}{}^{2})$ and is given by:

$$(\Sigma_{iB}{}^{2}) = E\left\{ \left[Min(R_{it} - B;0)\right]^{2} \right\} \tag{1}$$

With:

- R_{it} : Return on asset j during period t
- B : Investor specific benchmark return

The semivariances of the considered assets with respect to different targets are given in Exhibit 3:

Exhibit 3: Target Semivariances

Target Rate	Bond	IPD	Direct Infra+Util	ASX	Indirect Infra + Util
0.0%	0.49	2.00	0.09	33.21	20.10
1.5%	1.88	3.37	0.99	39.65	25.74
3.0%	5.20	5.65	3.87	47.63	33.13

The square root of (1) describes the semideviation of asset i with regard to a benchmark B, a common measure of downside risk. The complement to the covariance in the MPT optimization is depicted by the semicovariance (Σ_{ij}) between asset i and j with respect to a benchmark B. This is defined as follows:

$$\Sigma_{ij} = E\{Min(R_i - B,0) * Min(R_j - B,0)\} \tag{2}$$

The fact that this definition can be customized to any desired B and generates a symmetric semicovariance matrix

$$\Sigma_{ij} = \Sigma_{ji}$$

constitutes an advantage towards the traditional Hogan and Warren (1974) measure.

In order to derive the optimal asset allocation, the risk measure of a portfolio, defined as the semivariance, is minimized:

Minimize: $$\Sigma^2{}_{pB} \approx \sum_{i=1}^{n}\sum_{j=1}^{n} x_i x_j \Sigma_{ijB}$$

Subject to:

$$\sum_{i=1}^{N} x_i \overline{R}_i = \overline{R}_p$$

$$\sum_{i=1}^{N} x_i = 1$$

$$x_i \geq 0,\ i = 1, 2, \ldots\ldots, N \tag{3}$$

With:

- $\overline{R}_i$: Expected return on asset i
- $\overline{R}_p$: Expected portfolio return

3.4.3 Research Design

This study constructs mean-downside risk-efficient mixed-asset portfolios, including. stocks, government bonds, treasury bills and commercial real estate. The expected portfolio returns range from the return on a minimum-risk portfolio of up to 3.4% quarterly. The maximum achievable return is 3.69%, which, however, can only be gained when all funds are invested in indirect infrastructure. The benchmark returns within the downside risk optimization algorithms are 0%, 1.5%, and 3%. The first target level indicates that an investor is concerned mainly with the nominal preservation of capital. A target rate of 1.5% quarterly mirrors the Australian inflation rate in 2008, reflecting an investor whose main priority is the real preservation of capital. It is not a contradiction to consider an expected return which is above the target return. The implication is that, although the investor aims at achieving the expected return, only outcomes below the benchmark constitute a risk to him. The third target rate is set arbitrarily and is appropriate for investors who require higher benchmark returns. Although this number does not necessarily constitute a reasonable value – it is not practical to set a benchmark of 3% per quarter and to assess assets with a maximum expected return below that number – this benchmark is examined, so as to determine how allocations tend towards a relatively high target level. The parameter of risk aversion is set to “2”, which implies that the risk measured at the asset level is the target semivariance.

3.4.4 Asset Allocations

When the target rate of return is set to 0.0%, the allocation to indirect infrastructure increases, the higher the expected portfolio return is set, and the theoretical weights range between 0% and 78%. This is due to the fact that indirect infrastructure has proved to deliver the highest return of all considered assets, but is also inherent subject to downside risk. Therefore, indirect infrastructure is only allocated to the portfolio when relatively high returns must be achieved. For a return of 3.4%, the proportion of infrastructure in the portfolio amounts theoretically to 78%. Although this number is derived by the optimization algorithm, it must be interpreted with care, since it does not seem to be rational to have an exposure of 78% attributable to diversification issues. This high allocation is also due to the fact that no equities are incorporated into the mixed asset portfolio which, in turn, is caused by significant losses during the financial crisis.

Due to diverse risk-return characteristics, the case with direct infrastructure is different. The minimum semivariance portfolio has an exposure to direct infrastructure of 85%. The low level of downside risk, especially for a target of 0%, leads to this high proportion. Up to a quarterly portfolio return of 3.00%, the allocation to direct infrastructure diminishes to zero percent, since direct property, bonds and indirect infrastructure are incorporated. Therefore, the allocation to direct infrastructure is suggested to be situated within a range of 0% to 85%. However, in contrast to indirect infrastructure, direct infrastructure allocations are highest when a relatively safe portfolio has to be composed. But, as stated above, due to diversification issues, the overwhelming allocation to direct infrastructure has to be considered from a theoretical point of view.

These results demonstrate the role of infrastructure – direct as well as indirect – for investment portfolios when investors are downside risk averse: An allocation to infrastructure within a range of 0% up to 85% is suggested by the above optimization algorithm when stocks, bonds, property and direct as well as indirect infrastructure are considered. Taking into account lower expected returns, an exposure to direct infrastructure is preferable, whereby, for higher expected portfolio returns, the portfolio should be heavily weighted towards indirect infrastructure. This model obviously reveals the role and importance of infrastructure for asset allocation and demonstrates that infrastructure could play an important role in institutional investment portfolios.

Exhibit 4: Portfolio Allocations

Target 0%								
Bond	0.15	0.18	0.21	0.25	0.28	0.17	0.05	0.00
Property	0.00	0.11	0.17	0.23	0.29	0.31	0.31	0.22
Direct Infra+Util	0.85	0.62	0.42	0.22	0.03	0.00	0.00	0.00
ASX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect Infra + Util	0.00	0.09	0.20	0.30	0.41	0.52	0.64	0.78
SUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Portfolio Return	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40
Portfolio Risk	0.08	0.40	1.26	2.66	4.58	7.05	10.09	13.71

Target 1.5%								
Bond	8.00	0.29	0.30	0.31	0.23	0.12	0.02	0.00
Property	0.11	0.29	0.34	0.39	0.38	0.36	0.35	0.22
Direct Infra+Util	0.61	0.37	0.20	0.04	0.00	0.00	0.00	0.00
ASX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect Infra + Util	0.00	0.05	0.16	0.27	0.39	0.51	0.64	0.78
SUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Portfolio Return	2.05	2.20	2.40	2.60	2.80	3.00	3.20	3.40
Portfolio Risk	0.78	1.19413	2.34	4.09	6.47	9.54	13.29	17.78

Target 3.0%								
Bond	0.30	0.27	0.25	0.22	0.15	0.06	0.00	0.00
Property	0.28	0.47	0.49	0.50	0.48	0.45	0.37	0.22
Direct Infra+Util	0.42	0.25	0.14	0.03	0.00	0.00	0.00	0.00
ASX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect Infra + Util	0.00	0.01	0.13	0.24	0.37	0.49	0.63	0.78
SUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Portfolio Return	2.11	2.20	2.40	2.60	2.80	3.00	3.20	3.40
Portfolio Risk	2.89	3.21	4.73	6.95	9.90	13.63	18.15	23.58

These results do not change fundamentally when the target rate of return is increased to 1.5% and 3.0%. When increasing the quarterly target from 0.0% to 1.5%, the allocation to indirect infrastructure remains constant for high expected returns, but decreases for low to medium returns.

The proportion of direct infrastructure decreases significantly when the benchmark return increases. For a target return of 1.5%, direct infrastructure is replaced by bonds and direct property, for a target return of 3.0%. However, the weighting for direct infrastructure decreases even more, due to the increase in real estate. This might be caused by the significant increase of direct infrastructure's semicovariance, relative to the risk of the other assets, when the target return exceeds the 1% level.

The proportion of property in the portfolio rises for almost all levels of expected returns, when the target rate increases. Altering the target rate of return from 0% to 1.5%, leads to an increase in the allocation to bonds for low-to-medium expected levels of returns, but to a decrease for higher expected return levels. Altering the target rate to 3.0% diminishes the proportion of bonds in the portfolio for each level of expected return.

3.5 Concluding Remarks

This paper, on the one hand, contributes to the debate on whether or not infrastructure can be classified as real estate. The discussion, as well as the empirical investigation, yields at the conclusion that two distinct asset classes are present, even though infrastructure and real estate have some common characteristics. Especially the evaluation of correlation figures provides conclusive evidence of the different performance characteristics of infrastructure and real estate.

The portfolio allocation model as well, reveals some interesting results and suggests the benefit of substantial allocations to direct and indirect infrastructure ranging from 0% to 85%. However, the results obtained from this study must be interpreted with caution. The optimization algorithm does not include equities, due to their very poor performance during the financial crisis. However, due to diversification benefits, a rational investor will always include stocks in his portfolio. Since stocks are usually perceived as high risk – high return assets their inclusion is likely to reduce the allocation to indirect infrastructure at the upper end of the expected returns. Moreover, the portfolio model is not able to take into account some major characteristics of investing in direct infrastructure. Acquiring or selling a direct infrastructure project requires a considerable amount of transaction time, which, in turn, reduces the potential to react immediately to prevailing market trends. In addition, when investing in infrastructure, long-term contracts are imposed on investors by public agencies, considerably restricting flexibility. The very large lot size and indivisibility, especially impedes smaller investment funds in allocating a small proportion of infrastructure to their portfolios, which in turn constrains diversification. Furthermore, infrastructure is a relatively young, immature and illiquid asset class which lacks a secondary market, thus constituting a risk for an investor who intends to allocate funds to this market. According to these facts, it would be rational for investors to impose a risk premium when investing in direct infrastructure, something which should also be considered in an asset allocation framework. Furthermore, depending on the holding period of infrastructure assets, the incorporation of transaction costs might diminish the return on investment and therefore influence portfolio weights.

If the number of investors in the infrastructure market increases and the secondary market grows, these elements of uncertainty may decline, which, in turn, may induce a reduction in the required risk premium. Accordingly, it is possible that infrastructure returns will change fundamentally when the market becomes more sophisticated. This, of course, does not exclude the possibility that infrastructure and real estate return characteristics converge in the future. Nevertheless, a current view of real estate and infrastructure yields a picture of two different asset classes with the associated need to draw an explicit distinction between the two.

We conclude that infrastructure represents an attractive asset class, which can enhance the benefits of diversification and, therefore, the performance of institutional investment portfolios. Further research could usefully consider the pricing of infrastructure firms' securities. Thus, the question arises as to what constitutes the main factors driving infrastructure returns and whether infrastructure returns can be explained by conventional asset pricing models. Moreover, transaction costs as well as liquidity risk premia should be on the agenda, when an infrastructure asset allocation model is considered.

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4. Real Estate: A Victim of Infrastructure? Evidence from Conditional Asset Allocation

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Abstract

The emergence and increasing importance of the asset class "infrastructure" requires a reassessment of traditional portfolio strategies. Due to their underlying similarities, the inclusion of infrastructure might, in particular, affect the allocation to real estate. This study investigates the role of real estate in a multi-asset portfolio, when infrastructure and further (alternative) assets are considered. We use a novel dataset which allows, for the first time, the exact evaluation of direct infrastructure returns and its role in well diversified institutional investment portfolios. We assume correlations to be varying and investors to be downside risk averse. Our results underpin the significance of direct infrastructure for portfolio diversification and show that theoretical allocations to direct real estate are likely to be overestimated when direct infrastructure is not considered. Moreover, direct real estate and direct infrastructure constitute attractive investments for downside risk-averse investors, especially during bear market states. The results also indicate that allocations differ significantly with changes in investor-specific target rates.

4.1 Introduction

The emergence of a new asset class always raises the issue of the extent to which it should be included in institutional investment portfolios and which asset should be replaced. Private infrastructure investments[17] have received considerable attention during recent years and large institutional investors began to include or even increase the infrastructure allocations in their investment portfolios[18].

According to Mansour and Patel (2008), the entire global infrastructure universe is estimated to be worth $20.5 trillion (real estate: $11 trillion). The total global infrastructure project finance volume involving private participation was estimated to be at around US$ 242 billion in 2010 (Kjorstad 2011). The macroeconomic impacts and the importance of adequate infrastructure provision are significant (Röller and Wavermann, 2001) and the World Economic Forum recently highlighted underinvestment in infrastructure as one of three key global risks (WEF 2010). However, at the center of the need for private participation in infrastructure financing is a major imbalance of demand and supply. Up to 2030, global infrastructure requirements are estimated at about US$ 3 trillion per annum, while governments can only provide about US$ 1 trillion (OECD 2006). This development will further create diverse private investment opportunities in future years. The American Society of Civil Engineers (2009) estimates the need for infrastructure investments in the US alone to be at 2.2 trillion for the next five-year period.

The motivation of (institutional) investors to undertake infrastructure investments is straightforward. They are seeking for conservative, liability-matching, less complex and tangible assets which provide new sources of stable, attractive and risk-adjusted returns, as well as comprehensive diversification benefits – being a rationale alternative to real estate Due to their apparently underlying similarities, investors identify with infrastructure mainly assets that are related to real estate. Additionally, the fund structures are similar for both assets: That is unlisted private equity fund structures have a long track record for real estate investments and are now also used for infrastructure investments.[19] Both aspects of similar underlying characteristics *and* similar investment fund structures make infrastructure assets familiar to real estate investments, certainly at first glance.

[17] The infrastructure investment universe is highly diverse, but in general terms, infrastructure assets can be divided into two main categories: economic and social infrastructure. Economic infrastructure includes long lasting, large-scale physical structures like transportation and communication infrastructure, as well as energy and utility facilities and its main use is for essential economic services that enter many industries directly as common inputs. Social infrastructure, on the other hand, includes education, healthcare, waste disposal as well as judicial facilities and provides social benefits to the economy (Wagenvoort et al.2010).

[18] The US pension fund CalPERS, for example, intends to increase its infrastructure allocation from 0.5% to 1.5% within the next two years. Some Australian and Canadian pension funds already have an infrastructure share of over 10% (Inderst, 2009).

[19] Similar to real estate investments, private infrastructure investments (equity) can be subdivided into three different categories: Listed infrastructure investments (stocks, listed funds), unlisted infrastructure investments (unlisted funds) as well as direct investments.

Indeed, despite the diversity of infrastructure assets, the similarities in underlying infrastructure asset characteristics and real estate assets are obvious. Both asset classes most importantly have a physical and real-asset character, large investment lot sizes[20] which create high barriers of entry, long-term investment horizons, stable and predictable cash flow patterns during operating phases, income and capital return components, a dependency of asset pricing on valuations, expected inflation-hedging characteristics and diversification potential with respect to traditional assets.

In contrast to the obvious similarities, the differences between both assets are striking. Whereas property markets can be described as relatively competitive, infrastructure markets often reveal oligopolistic or even monopolistic structures. A further issue is the limited potential to acquire ownership of direct infrastructure assets, due to regulatory constraints, which often only allow user rights. Moreover, real estate, in general, may lend itself to appropriate alternative uses, whereas infrastructure assets are limited to very specific and restricted uses. Furthermore, there is a greater degree of transparency in the real estate market, than in the infrastructure market. Although the relationship between infrastructure and real estate has been documented theoretically, the research on infrastructure asset allocation and its relation to real estate in institutional investment portfolios, has received little attention in the academic literature, primarily as a result of the lack of comprehensive data on infrastructure transactions. According to Inderst (2010), this lack of a performance benchmark also prevents investors from allocating funds to infrastructure assets. Although there are remarkable differences between infrastructure and real estate, their abovementioned similar underlying characteristics might result in identical diversification benefits, inducing investors to face a trade-off between both assets. However, this observation is based only on theoretical considerations, rather than on fundamental empirical evidence.

In this paper, we aim to close this research gap and account for the role of real estate *and* infrastructure in investment portfolios, by employing a novel data set of returns on individual US infrastructure transactions. In contrast to other infrastructure return indices, this index series is not constructed synthetically from a listed series, but based on direct infrastructure cash flows. This innovation enables, for the first time, the measurement of actual direct infrastructure performance.

[20] Private infrastructure project finance is usually operated through a special purpose vehicle (SPV). Dependent on the maturity stage and/or the type and size of the infrastructure project, various different equity investors and debt lenders are involved. Although individual projects can be extremely large, the involvement of a variety of equity investors, along with high gearing ratios could reduce the lot size problem from an equity investor point of view. The median project deal size (debt plus equity) is estimated to be about $200-300 million (Araujo 2010).

The aim of this paper is twofold. Firstly, we determine theoretical asset weights for investment portfolios that contain real estate *and* infrastructure. Secondly, we assess the extent to which the inclusion of infrastructure assets affects the allocation to real estate and other asset classes.

We allow for the fact that unconditional asset allocations reflect a simple buy and hold strategy, but disregard time varying correlations across different market states. The asymmetric return relationship between the returns on various assets and those of the general market is well documented and provides a rationale for assessing a dynamic asset allocation strategy. Moreover, we account for the asymmetric return distributions[21] of different assets. The traditional mean variance (MV) framework introduced by Markowitz (1959) in modern portfolio theory (MPT) is typically applied to determine efficient allocations and investment strategies for portfolio managers. However, this methodology is based on the strict assumption that asset returns follow a symmetric bell-shaped distribution. Therefore, its application is limited when asset returns are skewed (and exhibit excess kurtosis). To account for non-normal return distributions, the present study determines mean-downside risk (DR) efficient portfolios. In contrast to the variance, downside risk measures do not treat up and down movements from the mean as equally undesirable, but account only for returns below a pre-specified target rate of return. This is more intuitive and more accurately reflects a rational investor's objectives[22].

Our analysis spans the period from Q2 1990 to Q1 2009. The results show that infrastructure is an important asset for portfolio diversification and that theoretical allocations to direct real estate are likely to be overestimated when direct infrastructure is not considered. Moreover, compared to direct real estate, direct infrastructure asset weights are very sensitive towards changes in investor-specific target returns. We also find that direct real estate *and* direct infrastructure constitute attractive investments for downside risk-averse investors, especially during equity market downturns. The remainder of the paper is structured as follows. The next section reviews the literature on infrastructure and real estate asset allocation. Sections three and four present the concept of downside risk and the applied data. The paper continues with a discussion of downside correlations and efficient portfolio sets. We close with some conclusions.

[21] Myer and Webb (1993, 1994), Young and Graf (1995), Lizieri and Satchell (1997), Liu and Mei (1998), Bond and Patel (2003), Liow and Sim (2004) and Lee, Robinson and Reed (2008) provide evidence that real estate returns are not normally distributed.

[22] An ample body of empirical literature shows that a downside move in return is far more detrimental to an investor than the same amount of upside gain. Ang et al. (2006) examine US data and show that investors demand a downside risk premium of approximately 6% per annum for stocks, which covary strongly with the market during market downturns.

4.2 Literature Review

The literature review is divided into two subsections. The first reviews the literature on international infrastructure performance, as well as on its theoretical importance to asset allocation. The second subsection reviews the relevant body of real-estate asset-allocation literature.
Despite the increasing importance of infrastructure as an asset class, the academic literature on the diversification benefits of infrastructure and its role in institutional investment portfolios is limited. The existing literature is based predominantly on listed infrastructure assets. This is caused by a lack of good quality direct performance data that would allow for a comprehensive analysis of underlying asset performance.[23]
Bond, Hwang, Mitchell, and Satchell (2007) employ the Macquarie Global Infrastructure Index and demonstrate that no alternative asset class, such as commodities, hedge funds or indirect infrastructure, provides the same level of risk reduction as property, when allocated to a portfolio of UK core assets. Peng and Newell (2007) investigate the risk adjusted performance and portfolio diversification benefits of Australian listed infrastructure funds, listed infrastructure companies and unlisted infrastructure funds over the eleven year period from 1995 to 2006. They show that infrastructure contributes to investment portfolios by generating the highest return, but that it also exhibits high volatility. They further present evidence of increasing correlations of unlisted infrastructure and property returns over time. Portfolio diversification benefits from the infrastructure sectors however, were limited, particularly with unlisted infrastructure. Newell and Peng (2008) further analyze the risk adjusted performance and portfolio diversification benefits of listed infrastructure in the US over the 2000 to 2006 period, and highlight the outstanding performance and significant diversification benefits from 2003 onwards. Newell et al. (2008) conducted the first academic work on infrastructure performance in China, by constructing a listed infrastructure time-series for Hong Kong and China between 1995 and 2006. They find that infrastructure delivers improved risk-adjusted returns over time, but they also mention a decreasing diversification effect. They also find strong linkages between listed infrastructure and listed commercial property markets in China. Finkenzeller, Dechant and Schaefers (2010) employ a sample of unlisted Australian infrastructure funds from Q4 1994 to Q1 2009 to proxy for direct infrastructure performance. Their results confirm the diversification benefits of direct infrastructure and reveal heavy portfolio weights for low-to-medium expected returns. When expected returns increase, indirect infrastructure is given a greater allocation. By using a similar Australian dataset for the Q3 1995 to Q2 2009 period, Newell et al. (2011) underpin the significant diversification bene-

[23] Due to the increasing importance of the asset for institutional investors, there already exists a rich body of industry research (see for example Goldman Sachs (2008), RREEF (2007), Idzorek, Armstrong (2009).

fits of unlisted infrastructure in a multi asset portfolio and furthermore report robust risk-adjusted unlisted infrastructure returns during the financial crisis. For the Indian market, Singhal et al. (2011) use some fundamental key data and show that listed Indian infrastructure stocks deliver strong risk-adjusted returns, compared with other infrastructure stocks in the Asia-Pacific region, globally as well as compared to general Indian and international equity markets. In order to overcome the data limitations regarding unlisted infrastructure performance data, Hartigan et al. (2011) synthetically construct an unlisted UK infrastructure series for the Q3 1998 to Q3 2008 period. The application of the series in the multi- asset portfolio context suggests allocations of up to 80 percent of total wealth to unlisted infrastructure and up to 20 percent to listed infrastructure.

In contrast to the diversification benefits of infrastructure, real estate and its role in institutional investment portfolios is well documented. Lee (2005) argues that the rationale for including direct real estate in a multi-asset portfolio is its diversification benefits, rather than its contribution to portfolio returns. He considers the return due to diversification (RDD) and justifies allocations of up to 20% to real estate for US mixed asset portfolios. Terhaar, Straub and Singer (2003) employ a broad range of alternative investment opportunities, including private equity, hedge funds and commodities, and simulate asset returns after identifying common factors in the data. They recommend a weighting of around 10% to real estate, 10% to alternative assets, roughly 50% to equities and 30% to bonds, when the investor has moderate liquidity needs and a moderately long investment horizon. However, the work of Hung, Onayev and Tu (2008) is closest to our analysis. They examine the role of direct and indirect US real estate and the benefits of a dynamic asset allocation strategy, which arises from time varying correlations. They consider a broad range of assets and derive an optimal proportion of direct real estate between 3% and 26%, when asset weights are constrained.

Although the concept of DR is intuitively more appealing than that MPT, there is only limited research employing an optimization algorithm based on DR, in order to determine efficient portfolios containing real estate. Sing and Ong (2000) estimate allocations for a quarterly set of Singaporean direct property, stock and bond returns from Q2 1983 to Q2 1997. Depending on the expected return, the proportion of property ranges from 3% to 90%. Cheng (2001) applies a bootstrap procedure to annual US data on stocks, bonds, T-bills and direct real estate from 1970 to 1998. He finds that the DR model produces allocations which are in accordance with actual practice in institutional investment portfolios. Depending on the target rate of return, allocations to direct real estate range from 0% to 14%. Sing and Ling (2003) use ex post Australian market parameters to construct a hypothetical property trust (HPT) return series and to examine the role of Singaporean REITs together with stocks and bonds. Their results reveal a large proportion of HPTs in the portfolio, which increases up to a maximum of 80% for high expected returns. From the perspective of a German and a US-based investor, Maurer and Reiner (2002) find real estate securities to be a good portfolio diversifier, when added to international stocks/bonds portfolios. Examining an ex post and an ex ante analysis, the authors find the reduction in downside risk to be the main source of diversification. Kroencke and Schindler (2010) examine efficient portfolios of real estate securities from eight countries over the 1990 to 2009 period. They find that MV optimization yields inherently misleading results and DR optimized portfolios show stronger out-of-sample performance – at least during time periods characterized by high market volatility.

4.3 The Concept of Downside Risk

The concept of downside risk dates back to Roy (1952) who addresses the concern of falling short of a certain target return by means of a "safety first" rule. Bawa and Lindenberg (1977) develop a Capital Asset Pricing Model in a mean lower partial moment (LPM) framework, generalizing the semicovariance measure of Hogan and Warren (1974) into an n-degree LPM structure.

Following Fishburn (1977), an n-degree Lower Partial Moment is defined as

$$LPM_n(\tau, r_i) = \int_{-\infty}^{\tau} (\tau - r_i)^n dF(r_i) \tag{1}$$

where τ represents the target rate of return, r_i is the return on asset i, $dF(r_i)$ characterizes the probability density function of the return on asset i and n is the parameter of risk aversion. Bawa (1975) and Fishburn (1977) derive the relationship between LPM and stochastic dominance, and prove that decisions taken on the basis of LPM (n = 0, 1, 2) are consistent with the stochastically dominant decisions (1st, 2nd, 3rd degree).

Consistent with Bernoulli's expected utility criterion, Fishburn (1977) proposes a utility function given by

$$U(r) = r \qquad for\ all\ r \geq \tau \tag{2}$$

$$U(r) = r - k(\tau - r)^n \qquad for\ all\ r \leq \tau \tag{3}$$

$$\text{With } k+1 = \frac{U(t) - U(t-1)}{U(t+1) - U(t)} \tag{4}$$

The part of the utility function below the target return can express various risk preferences, such as risk aversion for n > 1, neutrality for n = 1, and risk seeking for 0 < n < 1. Depending on the parameter of risk aversion, the utility function is convex (n > 1), concave (0 < n < 1) or linear (n = 1). Given that returns above the benchmark are captured in the expected return, risk neutrality is assumed to imply linearity in this part of the utility function.

Nantell and Price (1979) and Harlow and Rao (1989) generalize the models of Hogan and Warren (1974) and Bawa and Lindenberg (1977), by specifying risk as deviations below any arbitrarily chosen target rate of return that does not need to be equal to the risk free rate of return. The Co-Lower Partial Moment (CLPM) of order n between the returns r_i on asset i and r_j on asset j is, therefore, given by:

$$CLPM_n(\tau, r_i, r_j) = \int_{-\infty}^{\tau}\int_{-\infty}^{+\infty} (\tau - r_i)^{n-1}(\tau - r_j)\, dF(r_i, r_j) \tag{5}$$

$$CLPM_n(\tau, r_i, r_j) \neq CLPM(\tau, r_j, r_i) \text{ when } i \neq j \tag{6}$$

$$CLPM_n(\tau, r_i, r_j) = CLPM(\tau, r_j, r_i) \text{ when } i = j \tag{7}$$

This measure of return dependence between asset *i* and *j* expresses the extent to which the risk of underperformance of asset *i* is diversified away by asset *j*. However, one should note that this is not equal to the diversification of a shortfall of asset *j* by asset *i*, which leads to an asymmetric CLPM matrix. Efficient portfolios are determined by constructing a convex combination of risky assets N, which is stochastically dominant, by providing the minimum risk for all levels of expected return to a downside risk-averse investor. The algorithm is based on Harlow and Rao's (1989) unrestricted version of Bawa's and Lindenberg's (1977) gerneralized CLPM, which can be presented formally as:

Minimize:

$$LPM_p = \sum_{i=1}^{N}\sum_{j=1}^{N} x_i x_j CLPM_n(\tau, x_i, x_j) \tag{8}$$

Subject to:

$$\sum_{i=1}^{N} x_i \bar{r}_i = \bar{r}_p \tag{9}$$

$$\sum_{i=1}^{N} x_i = 1 \tag{10}$$

$$x_i \geq 0, i = 1, 2, \ldots, N \tag{11}$$

With:

- x_i: Proportion of an investor's funds allocated to asset i
- $\bar{r}_i$: Expected return on asset i
- $\bar{r}_p$: Expected portfolio return

The DR methodology prefers positively skewed assets. This contradicts Cheng (2001), who proposes the DR algorithm to include assets with negative skewness, as fewer returns are situated below a certain target return. Even if a positive skewness describes a return distribution with more values situated to the left of the mean, a positively skewed investment tends to generate lower losses than assets with negative skewness. Therefore, when losses occur, they are smaller and gains are larger, compared to a negatively skewed investment. Beyond that, an asset's DR is not only characterized by its skewness, but also by its kurtosis. DR-averse investors prefer a lower kurtosis, due to the less frequent occurrence of extremely negative returns. Consequently, both measures have to be examined simultaneously. An asset whose return distribution is characterised by negative skewness and positive (excess) kurtosis in its return distribution is inherent to an increased probability of producing significant negative returns. An asset whose return distribution is characterised by positive skewness and positive (excess) kurtosis is inherent to an increased probability of producing significant positive returns.

4.4 Data

We employ quarterly US total return data from ten different asset classes, which are deflated by the consumer price index. In particular, we consider direct real estate, direct infrastructure, large cap stocks, small cap stocks, commodities, REITs, government bonds, cash, indirect infrastructure and private equity. The optimization is performed both unconditionally and conditionally. The unconditional optimization considers the entire return sample from Q2 1990 to Q1 2009, whereas the conditional optimization draws a distinction between up markets and down markets. An up market is classified as a situation in which the quarterly real market return – illustrated by the real return on the S&P 500 total return index – is above the quarterly median real market return. The opposite holds for down markets. According to this classification, 38 up and 38 down market states are identified. This approach is in accordance with Hung et al. (2008).

The TBI Index, which is published by the MIT center for Real Estate is applied to illustrate direct real estate performance. The index is based on the NCREIF index portfolio and is not subject to lagging and smoothing effects. The direct infrastructure performance index is provided by the Center of Private Equity Research (CEPRES) and is a sub-index of a more general CEPRES dataset of private equity investments which has been used in former studies including Krohmer et al. (2009), Franzoni et al. (2011) and Füss and Schweizer (2011). The infrastructure index covers a sample of 788 individual operating infrastructure projects in the US and is based on a broad reporting sample of 135 global infrastructure equity investors. The index methodology is in accordance with Peng (2001) and is based on the Method of Moment Repeat Sales Regression (MM-RSR). In Peng's original approach to determining a venture capital index, his dataset is based on financing rounds of various venture capital firms[24]. The initial financing round at time t_0 is employed to determine the actual price P_0 of the investment project. With the next financing round at t_1, the new value P_1 of the investment is established. This process continues through each financing round. An issue with the data of CEPRES is that the base data does not consist of financing rounds, but is derived from cash flows, and the matching financing rounds are unknown. Therefore, prices are estimated by using the cash flows (net) themselves. With these estimated prices, one can proceed with the methodology proposed by Peng (2001). In order to estimate prices of investments using cash flows, the IRR from each cash flow is determined. The initial cash flow in t_0 constitutes P_0. By using the IRR of the cash flow series, P_0 is compounded until the next subsequent cash flow. This results in an estimation of the value P_1 which corresponds to the interest gained at time t_1. Adding the costs (or subtracting the gains) for the interests acquired (or sold) at time t_1.to the actual value that was acquired at t_1, results in the total worth of the held interests. [25] For a more formal illustration of this process, refer to Schmidt and Ott (2006).

To aid comparison with unlevered real estate data and to demonstrate unbiased direct infrastructure performance, the index is corrected for gearing. The capitalization of the index adds up to around $24.3 billion of invested equity and only includes sectors which are in accordance with the definition of infrastructure from Kaserer et al. (2009). The relative high weights of health care, energy and telecom assets are in accordance with the investment objectives of

[24] Financial rounds could refer to first financial rounds, follow-on investments, IPOs, amortization or write offs.
[25] When the subsequent values of the initial cash are not all positive, the original cash flow series is divided into smaller series.

various investors and reflect the weights of institutional infrastructure investments. Together with a sufficient number of transactions and a high market capitalization, the index constitutes an appropriate tool for benchmarking direct infrastructure performance in the US. exhibit 1 shows the amount of invested capital and the respective number of realized transactions each year. These deals are – together with previous transactions – used to extract cash flows from which the index is constructed. As the private participation in infrastructure projects experienced rapid growth in the late 1990s, the number of deals increased rapidly within this time period, and then declined over the course of the dot.com bubble and again during the recent financial crisis. exhibit 2 shows the average sector weights, which are calculated according to capital invested over the entire sample period. The average index shares are 35% for social (health care, waste/recycling) and 65% for economic (transportation, telecom, energy, alternative energy, construction) infrastructure.

Exhibit 1: Capital Investment and Number of Deals for the Direct US Infrastructure Index

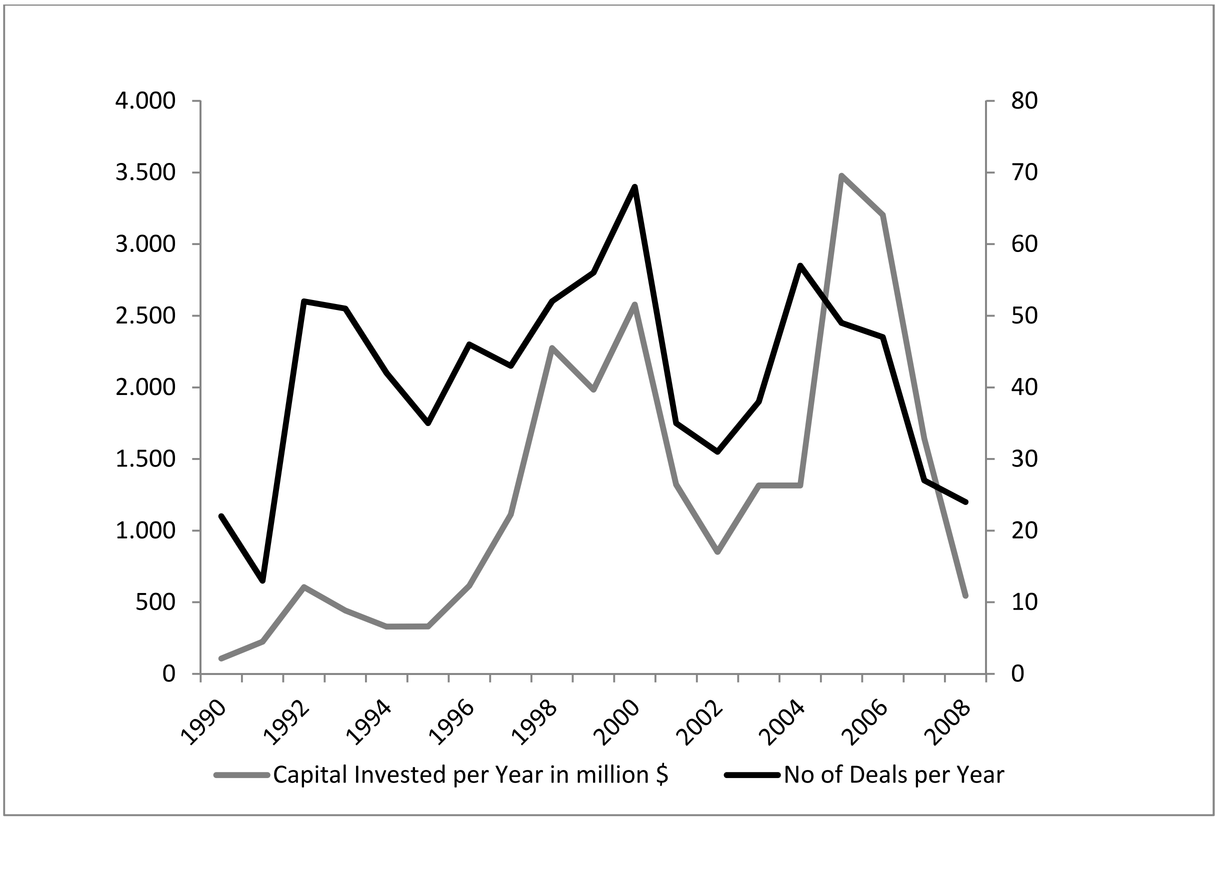
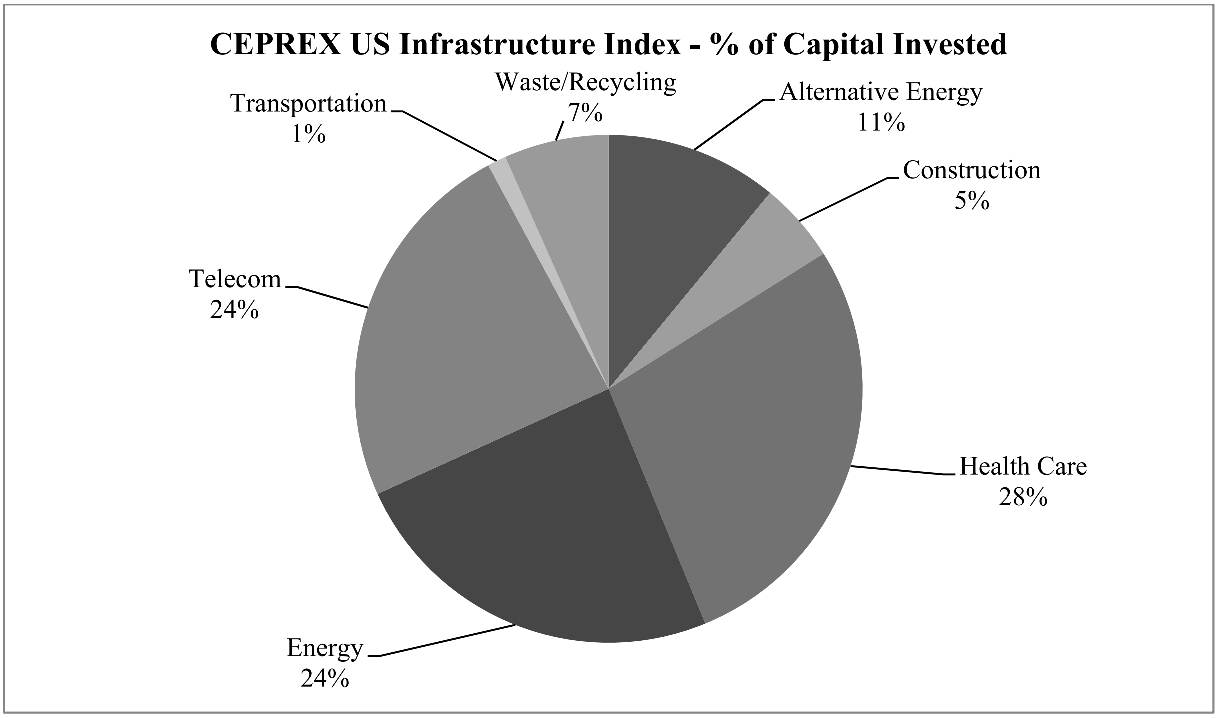


Exhibit 2: Infrastructure Index Sector Weights



The source for indirect infrastructure returns is the UBS US Infrastructure & Utilities index, which is obtained from Bloomberg. The Cambridge Associates US Private Equity Index provides total return data on transactions of 823 US private equity funds. These returns are net of fees, expenses and carried interest. All remaining assets are collected from Thomson Datastream. The FTSE US Large Cap index represents large cap stock returns, whereas the S&P 600 Small Cap index proxies returns from equities with low market capitalization. The FTSE/NAREIT US Equity REITs index reflects total returns from publicly traded real estate. An investment in cash is represented by the JP Morgan US Dollar Liquidity Fund A, which is designed to offer its investors a high level of liquidity and constitutes a low risk/low return investment. The US Benchmark 10 Year DS Government Index reflects the performance of US government bonds. Return data on commodities are taken from the Goldman Sachs Commodity index. These returns include roll and collateral returns. The three month Treasury bill is employed as a risk free investment and, as illustrated above, the S&P 500 is used to separate up from down market states. Data for all assets are available from Q2 1990 to Q1 2009. Contrary to trading most financial assets, buying and selling direct real estate and direct infrastructure evokes high transaction costs[26], which reduce returns. Round trip costs of 6%[27] are employed for US real estate transactions. Infrastructure transactions costs are, to a large

[26] The liquidity of the real estate and the infrastructure market is not likely to be constant over time which might result in varying transaction costs. However, for reasons of simplicity, we do not differentiate.
[27] We thank David Geltner for providing this information.

extent, independent of the size of the project, since they all require general services like technical, legal and financial advisory, as well as a sound estimation of demand risk. As a result, the cost can amount to a maximum of 10% of total project cost. Average infrastructure projects evoke round trip costs of about 5.5%[28]. However, actual transaction costs depend on the holding period of assets. Based on the findings of Fisher and Young (2000) and Geltner and Pollakowski (2007), the average institutional holding period of direct real estate is roughly ten years. According to the findings of Kaserer et al. (2009), the average duration of infrastructure investments is four years. This average holding period seems to be very short for direct infrastructure investments. However, one has to consider that there is a huge difference between the average concession period which is agreed between the government and the SPV and the holding period of an individual equity investor. While concession periods agreed between the regulator and the SPV, is around 30 years across all sectors, on average, an individual investor might have shorter holding periods, depending on strategic issues, such as the stage of the infrastructure project (OECD, 2010). Due to the growing maturity of the market and the increasing involvement of long-term investors, the average holding is likely to rise over the next years. We use this information from Geltner and Pollakowski (2007) and from Kaserer (2009) to adjust direct real estate and direct infrastructure returns.

Since investors are not homogenous, but have different investment objectives, different benchmark returns are considered. These are 0.0%, 0.5%, 1.0%, and 2.0% real return quarterly. The first target level indicates that an investor is mostly concerned with the real preservation of capital. A target rate of 0.5% reflects the objective of a conservative investor attempting to achieve a surplus over the capital preservation level which meets certain liabilities (pension fund etc.). The 1.0% target rate reflects a core plus investor aiming to raise his capital stock in a risk-sensitive manner. The last target rate represents an opportunistic investor, who is already concerned when returns fall below a relatively high benchmark. It is not a contradiction to consider an expected return which exceeds the target return. The implication is that, although the investor aims to achieve the expected return, only outcomes below the benchmark constitute a risk to him.

[28] We thank various institutional infrastructure investors and consultants for providing this information.

4.5 Descriptive Statistics and Downside Risk

The descriptive statistics for unconditional asset returns are summarized in exhibit 3. The requirement for an approach which allows for asymmetric return distributions is evident, as most assets exhibit significant skewness and/or kurtosis. Jarque Bera tests indicate non-normal return distributions for all assets, apart from infrastructure stocks. Private equity provides the highest return over the entire period whereas cash performs worst, but is also exposed to the smallest downside risk. Direct real estate outperforms direct infrastructure but entails a higher level of downside risk. exhibit 4 and exhibit 5 present descriptive statistics for conditional returns. The non normal distribution of the majority of asset returns is still evident when the sample is split into up- and down markets. Equities, commodities and private equity outperform in up markets, direct real estate, direct infrastructure and private equity yield attractive returns in down markets.

We employ Sortino-ratios S_i to determine downside risk adjusted excess target returns. These are given by:

$$S_i = \frac{r_i - \tau}{\sqrt{LPM_{r_i}\ (\tau, r_i)}} \qquad (12)$$

Due to the small downside risk of cash, this asset class provides an attractive risk-return tradeoff for a benchmark of 0.0%. For higher target returns, private equity yields the highest risk adjusted returns. Direct infrastructure and direct real estate returns are not as prone to falling short of a certain target rate as returns from stocks, commodities and REITs. Therefore, these assets provide higher risk adjusted returns for three out of four target rates. In up markets, depending on the target rate, cash, large caps or small caps prove to be superior in terms of risk-adjusted returns. In down markets, the same holds for cash, bonds and private equity.

Exhibit 3: Summary Statistics of Unconditional Asset Performance Q2 1990 to Q1 2009

Asset	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr. Stocks	Private Equity
Mean Return	1,62	1,43	1,50	1,80	1,16	1,64	1,33	0,63	1,49	2,86
Median Return	1,50	1,47	1,84	2,50	1,54	2,87	1,06	0,75	3,43	3,07
Std. Dev	4,10	3,47	8,23	9,96	13,06	9,14	3,99	0,45	8,49	5,34
Sample Skewness	0,38	0,64	-0,77	-0,89	0,15	-0,89	0,61	-0,42	-0,12	-0,49
		**	***	***		***	**			*
Sample Kurtosis	3,24	4,62	2,88	2,21	4,59	2,52	0,53	-0,96	1,30	1,39
	***	***	***	**	***	**				
Jarque Bera Statistics	29,37	62,09	28,73	22,15	56,55	26,06	5,09	5,15	4,29	7,67
	***	***	***	***	***	***	*	*		**
Sample LPM										
Target = 0%	4,37	2,65	30,66	46,68	72,76	39,73	3,30	0,00	30,17	7,41
Target = 0.5%	5,29	3,31	33,13	49,70	76,95	42,54	4,42	0,07	32,91	8,42
Target = 1%	6,38	4,18	35,81	52,91	81,37	45,54	5,77	0,33	35,85	9,57
Target = 2%	9,23	6,62	41,82	60,00	90,96	52,18	9,23	2,07	42,34	12,39
Sortino Ratio										
Target = 0%	0,78	0,88	0,27	0,26	0,14	0,26	0,73	10,18	0,27	1,05
Target = 0.5%	0,49	0,51	0,17	0,18	0,08	0,18	0,39	0,50	0,17	0,81
Target = 1%	0,25	0,21	0,08	0,11	0,02	0,10	0,14	-0,64	0,08	0,60
Target = 2%	-0,12	-0,22	-0,08	-0,03	-0,09	-0,05	-0,22	-0,95	-0,08	0,24
Number of Quarters	76	76	76	76	76	76	76	76	76	76

***,** and * denotes significance at 1%, 5% and 10%, respectively

Exhibit 4: Summary Statistics of Conditional Asset Performance Up Markets Q2 1990 to Q1 2009

Asset	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr. Stocks	Private Equity
Mean Return	1.61	1.78	5.61	6.66	4.96	4.40	0.98	0.69	2.03	3.69
Median Return	1.05	1.83	5.77	6.40	4.38	4.29	1.12	0.88	3.43	3.64
Std. Dev	3.03	3.63	6.34	7.59	11.74	7.36	3.31	0.45	6.49	4.53
Sample Skewness	0.18	-0.21	0.35	-0.04	1.80	-0.06	0.10	-1.00	-0.52	-0.22
					***			**		
Sample Kurtosis	0.44	3.74	0.92	-0.05	6.96	2.04	-1.16	-0.11	0.62	0.63
		***			***	**				
Jarque Bera Statistics	0.27	15.56	1.37	0.07	74.47	4.23	2.20	5.88	1.80	0.54
		***			***			*		
Sample LPM										
Target = 0%	1.56	3.45	3.15	5.61	17.51	10.99	2.85	0.007	14.78	2.92
Target = 0.5%	2.12	4.09	3.81	6.49	19.49	12.11	3.93	0.07	16.64	3.45
Target = 1%	2.87	4.89	4.57	7.47	21.67	13.35	5.24	0.29	18.69	4.08
Target = 2%	5.11	7.10	6.41	9.72	26.58	16.27	8.63	1.91	23.42	5.77
Sortino Ratio										
Target = 0%	1.29	0.96	3.16	2.81	1.19	1.33	0.58	8.23	0.53	2.16
Target = 0.5%	0.76	0.63	2.61	2.42	1.01	1.12	0.24	0.70	0.38	1.72
Target = 1%	0.36	0.35	2.15	2.07	0.85	0.93	-0.01	-0.57	0.24	1.33
Target = 2%	-0.17	-0.08	1.42	1.49	0.57	0.59	-0.35	-0.95	0.01	0.70
Number of Quarters	38	38	38	38	38	38	38	38	38	38

***,** and * denotes significance at 1%, 5% and 10%, respectively

Exhibit 5: Summary Statistics of Conditional Asset Performance Down Markets Q2 1990 to Q1 2009

Asset	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr. Stocks	Private Equity
Mean Return	1.64	1.08	-2.61	-3.06	-2.63	-1.11	1.68	0.58	0.95	2.03
Median Return	2.15	0.68	-1.15	-1.84	-1.95	-0.48	1.06	0.52	3.10	2.07
Std. Dev	4.99	3.31	7.89	9.75	13.36	9.98	4.59	0.45	10.17	5.98
Sample Skewness	0.39	1.74	-1.40	-1.33	-0.71	-0.99	0.68	0.13	0.09	-0.44
		***	***	***	*	**	*			
Sample Kurtosis	2.63	7.95	3.59	2.48	2.69	1.88	0.48	-1.23	0.86	1.31
	**	***	***	**	***	*				
Jarque Bera Statistics	8.13	90.67	25.53	16.74	10.59	9.26	2.83	2.49	0.62	2.72
	**	***	***	***	***	***				
Sample LPM										
Target = 0%	7.17	1.86	58.16	87.75	128.01	68.48	3.75	0.00	45.56	11.91
Target = 0.5%	8.45	2.54	62.45	92.90	134.40	72.97	4.91	0.07	49.19	13.39
Target = 1%	9.88	3.46	67.04	98.36	141.08	77.74	6.30	0.36	53.02	15.05
Target = 2%	13.35	6.15	77.23	110.28	155.33	88.10	9.83	2.22	61.26	19.02
Sortino Ratio										
Target = 0%	0.61	0.79	-0.34	-0.33	-0.23	-0.13	0.87	21.68	0.14	0.59
Target = 0.5%	0.39	0.36	-0.39	-0.37	-0.27	-0.19	0.53	0.30	0.06	0.42
Target = 1%	0.20	0.04	-0.44	-0.41	-0.31	-0.24	0.27	-0.70	-0.01	0.27
Target = 2%	-0.10	-0.37	-0.52	-0.48	-0.37	-0.33	-0.10	-0.95	-0.13	0.01
Number of Quarters	38	38	38	38	38	38	38	38	38	38

***,** and * denotes significance at 1%, 5% and 10%, respectively

The performance of direct infrastructure assets is in accordance with our expectations and the underlying characteristics of the asset class. Direct infrastructure is a low risk – low return asset which delivers positive returns independent of the market state. Infrastructure stocks show similar returns patterns but exhibit much higher volatility.

4.5 Downside Correlations

Exhibit 6 presents unconditional downside correlations for varying targets. Correlations are estimated by dividing the CLPM between asset i and j, by the square roots[29] of the LPMs from asset i and j, whereby all risk measures are conditional on the shortfall occurrence of asset i.

$$\rho_{ij}^{n} = \frac{\int_{-\infty}^{\tau}\int_{-\infty}^{+\infty}(\tau-r_j)^{n-1}(\tau-r_i)\,dF(r_i,r_j)}{\sqrt[n]{\int_{-\infty}^{\tau}(\tau-r_i)^{n}\,dF(r_i)}\;\sqrt[n]{\int_{-\infty}^{\tau}(\tau-r_j)^{n}\,dF(r_j)}} \tag{14}$$

In accordance with the CLPM, this yields an asymmetric downside correlation matrix. Therefore, the interpretation is not straightforward, but the figures in the rows of the downside correlation matrix indicate the extent to which the underperformance of one asset is diversified by another asset[6]. For instance, in exhibit 6, the number in the second upper left field (0.24) of

[29] Depending on the parameter of risk aversion n, it has to be the n-th root.

the first row describes the extent to which a shortfall below the target of direct infrastructure is diversified away by a movement in the direct real estate return.
As a general pattern, correlations increase with rising targets, which indicates decreasing diversification benefits. This is an intuitive result, which stems from the construction of downside correlations. Since the correlation measures are sensitive to the target return, a common underperformance is more likely, the higher this target is set. In terms of unconditional correlations, direct infrastructure, bonds and cash provide attractive diversification benefits, since they diversify the shortfall risk of most other assets. As a consequence of its low returns, the diversification benefits of cash diminish very rapidly when the benchmark return increases. The diversification potential of bonds and direct infrastructure remains relatively stable up to a target rate of 1.0% and 2.0%, respectively, indicating that these assets might play an important role in efficient allocations. The diversification benefits of direct infrastructure are in accordance with expectations. As direct infrastructure returns are largely independent of economic cycles, it makes sense that correlations with other, more cyclical, assets as stocks, commodities or REITs are low. Negative correlations to bonds might result from the fact that bond returns suffer in periods of high inflation whereas direct infrastructure is assumed to be a good hedge against inflation. Direct real estate returns are significantly positively related to direct infrastructure and private equity downside returns, but diversify cash and bond returns up to a target of 1.0%. Returns from REITs provide a good hedge against below-target performance from direct infrastructure, but are significantly related to equity downside returns, especially small caps. This is in accordance with prior research, which identifies REITs as behaving like small cap stocks (Glascock et. al., 2000). exhibit 7 and exhibit 8 reveal conditional downside correlations in both up- and down markets. The time varying characteristics are obvious, as downside correlations differ substantially in different market states. While direct real estate compensates for the below target performance of most other assets in bull markets, only downside returns on bonds and cash are significantly diversified in bear markets. However, the diversification of downside bond returns, together with high risk adjusted returns in bear markets, indicates the important role of direct real estate when the equity market performs badly. The diversification benefits of stocks, commodities, REITs and private equity are, in a similar manner to direct real estate, also predominantly apparent in bull markets. The fact that REIT correlations to other assets are lower during bull markets, but increase during down markets, is in accordance with the findings of Hung, Onayev and Tu (2008) who, however, do not examine any downside correlations. In contrast to most other assets, the diversification benefits of direct infrastructure and bonds do not change as signifi-

cantly with the market state but diversify the downside returns of most other asset in bull, as well as in bear markets. Together with high risk-adjusted returns, this points towards a significant allocation to direct infrastructure and bonds in down markets.

Exhibit 6: Unconditional Downside Correlations Q2 1990 to Q1 2009

Target = 0.0%	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr.Stocks	Private Equity
Real Estate	1.00	0.13	0.27	0.24	0.46	0.33	-0.60	-0.65	0.05	0.11
Infrastructure	0.24	1.00	-0.23	-0.40	-0.09	-0.23	-0.43	-0.58	-0.07	-0.15
Large Caps	0.05	-0.28	1.00	0.80	0.53	0.51	-0.26	-0.59	0.42	0.36
Small Caps	0.06	-0.52	0.80	1.00	0.50	0.69	-0.31	-0.64	0.23	0.13
Commodities	0.07	-0.26	0.52	0.46	1.00	0.38	-0.38	-0.63	0.24	0.06
REITS	0.15	-0.46	0.55	0.65	0.45	1.00	-0.42	-0.64	0.38	0.18
Bonds	-0.32	-0.42	-0.05	-0.14	-0.24	-0.12	1.00	-0.64	0.01	-0.44
Cash	-0.76	-0.75	-0.24	-0.42	-0.49	-0.31	-0.05	1.00	-0.17	-0.40
Infr. Stocks	-0.02	-0.16	0.41	0.21	0.19	0.23	-0.23	-0.55	1.00	0.32
Private Equity	0.46	0.08	0.69	0.51	0.47	0.45	-0.28	-0.61	0.52	1.00
Target = 2.0%	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr. Stocks	Private Equity
Real Estate	1.00	0.32	0.33	0.26	0.32	0.34	-0.10	0.70	0.23	0.28
Infrastructure	0.40	1.00	0.03	-0.14	-0.01	-0.06	-0.10	0.68	0.10	0.10
Large Caps	0.27	0.03	1.00	0.82	0.56	0.58	0.08	0.64	0.49	0.48
Small Caps	0.29	-0.21	0.83	1.00	0.55	0.68	0.09	0.64	0.32	0.30
Commodities	0.31	0.06	0.61	0.51	1.00	0.45	-0.08	0.67	0.38	0.25
REITS	0.42	-0.10	0.58	0.69	0.47	1.00	-0.07	0.67	0.50	0.36
Bonds	0.06	0.00	0.20	0.07	-0.05	0.10	1.00	0.89	0.13	-0.19
Cash	0.07	0.16	0.10	-0.01	0.04	0.00	0.20	1.00	0.10	-0.16
Infr.Stocks	0.35	0.32	0.51	0.30	0.27	0.33	0.13	0.81	1.00	0.51
Private Equity	0.60	0.32	0.68	0.52	0.39	0.44	-0.01	0.62	0.56	1.00

Exhibit 7: Conditional Downside Correlations Up Markets Q2 1990 to Q1 2009

Target = 0.0%	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr. Stocks	Private Equity
Real Estate	1.00	0.41	-0.62	-0.50	0.04	-0.17	-0.42	-0.75	-0.21	-0.24
Infrastructure	0.33	1.00	-0.43	-0.47	-0.22	-0.23	-0.63	-0.65	-0.11	-0.06
Large Caps	-0.41	-0.41	1.00	0.08	0.27	-0.26	-0.17	-0.67	-0.05	-0.27
Small Caps	0.15	-0.50	-0.23	1.00	-0.28	0.16	-0.08	-0.92	-0.27	-0.22
Commodities	-0.36	-0.29	-0.36	-0.49	1.00	-0.47	-0.59	-0.78	-0.08	-0.40
REITS	-0.19	-0.70	-0.17	-0.07	-0.21	1.00	0.13	-0.45	0.14	-0.35
Bonds	-0.39	-0.58	-0.52	-0.67	-0.78	-0.30	1.00	-0.81	-0.32	-0.65
Cash	-0.83	-0.84	-0.55	-0.62	-0.55	-0.19	-0.31	1.00	-0.41	-0.58
Infr. Stocks	-0.18	-0.26	-0.38	-0.44	-0.21	-0.27	-0.14	-0.67	1.00	0.02
Private Equity	0.08	0.15	-0.13	0.00	0.01	-0.27	-0.11	-0.70	0.57	1.00
Target = 2.0%	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr. Stocks	Private Equity
Real Estate	1.00	0.32	-0.41	-0.37	-0.05	-0.09	0.29	0.72	0.11	-0.05
Infrastructure	0.55	1.00	-0.39	-0.49	-0.28	-0.32	0.07	0.55	0.04	0.02
Large Caps	0.07	-0.21	1.00	0.33	0.26	0.04	0.38	0.72	0.19	0.04
Small Caps	0.53	-0.23	0.12	1.00	-0.08	0.30	0.51	0.69	0.00	0.01
Commodities	0.03	0.00	-0.27	-0.38	1.00	-0.38	-0.16	0.64	0.12	-0.18
REITS	0.21	-0.27	-0.12	0.03	-0.22	1.00	0.44	0.66	0.33	0.00
Bonds	0.36	0.02	-0.26	-0.43	-0.54	-0.11	1.00	0.86	-0.03	-0.38
Cash	0.12	-0.01	-0.39	-0.52	-0.23	-0.29	0.34	1.00	0.01	-0.32
Infr. Stocks	0.30	0.14	-0.31	-0.41	-0.14	-0.15	0.34	0.75	1.00	0.32
Private Equity	0.45	0.30	-0.05	0.00	-0.09	-0.16	0.32	0.60	0.64	1.00

Exhibit 8: Conditional Downside Correlations Down Markets Q2 1990 to Q1 2009

Target = 0.0%	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr. Stocks	Private Equity
Real Estate	1.00	0.04	0.55	0.51	0.52	0.52	-0.64	-0.68	0.15	0.28
Infrastructure	0.21	1.00	0.07	-0.28	0.12	-0.24	-0.41	-0.48	-0.05	-0.26
Large Caps	0.09	-0.29	1.00	0.84	0.55	0.60	-0.26	-0.61	0.48	0.45
Small Caps	0.05	-0.57	0.86	1.00	0.55	0.75	-0.33	-0.62	0.26	0.17
Commodities	0.16	-0.29	0.77	0.72	1.00	0.63	-0.34	-0.65	0.33	0.19
REITS	0.21	-0.41	0.72	0.76	0.72	1.00	-0.49	-0.72	0.42	0.26
Bonds	-0.33	-0.34	0.52	0.32	0.15	0.06	1.00	-0.49	0.25	-0.24
Cash	-0.71	-0.63	0.19	-0.08	-0.47	-0.87	0.40	1.00	-0.20	-0.31
Infr.Stocks	0.05	-0.11	0.78	0.52	0.42	0.46	-0.26	-0.53	1.00	0.43
Private Equity	0.52	0.07	0.85	0.59	0.72	0.61	-0.31	-0.59	0.52	1.00
Target = 2.0%	Real Estate	Infrastructure	Large Caps	Small Caps	Commodities	REITS	Bonds	Cash	Infr. Stocks	Private Equity
Real Estate	1.00	0.33	0.61	0.54	0.53	0.54	-0.28	0.73	0.28	0.43
Infrastructure	0.35	1.00	0.37	0.16	0.23	0.13	-0.23	0.81	0.14	0.16
Large Caps	0.29	0.08	1.00	0.86	0.60	0.65	0.04	0.65	0.53	0.54
Small Caps	0.26	-0.22	0.89	1.00	0.60	0.73	0.05	0.65	0.35	0.36
Commodities	0.38	0.09	0.83	0.78	1.00	0.70	-0.07	0.71	0.48	0.37
REITS	0.49	-0.03	0.74	0.80	0.75	1.00	-0.19	0.71	0.53	0.43
Bonds	-0.10	-0.01	0.64	0.55	0.35	0.32	1.00	0.93	0.23	-0.01
Cash	0.05	0.33	0.46	0.38	0.26	0.20	0.09	1.00	0.15	-0.04
Infr. Stocks	0.36	0.42	0.82	0.61	0.51	0.57	0.06	0.87	1.00	0.57
Private Equity	0.65	0.36	0.85	0.66	0.63	0.66	-0.09	0.65	0.54	1.00

4.6 Asset Allocations

4.6.1 Unconditional Portfolios

Unconditional DR portfolios[30] are presented in exhibits 9A and 9B. One striking result is the sensitivity of asset weights to changes in the target rate. This underpins the need for an approach that allows for varying benchmark returns. Direct infrastructure and bond allocations are significantly affected, as their allocations apparently decrease with rising targets. This is due to a strong increase in downside correlations when the target rate increases. However, both assets are significantly weighted in unconditional portfolios, which is not attributable to their performance but a result of low exposure to downside risk and good diversification benefits. This is in accordance with the distributional characteristics of direct infrastructure returns as they exhibit significant positive skewness *and* kurtosis – which is preferred by the optimization algorithm. Private equity and cash allocations tend to rise with higher target levels. A high exposure to cash does not seem to be intuitively correct, when the target return is high. However, even for high targets, cash is not exposed to high downside risk and is therefore allocated to low and medium expected return portfolios. Direct real estate allocations range from 0% to 7% of an investor's total wealth and are highest in medium-expected-return portfolios. These weights tend to rise to a benchmark return of 1.0% and then decrease for the highest target returns. Direct real estate allocations are lower than in most other studies and

[30] The Exhibits on target returns 0.5 and 1.0 percent for all scenarios are available from the authors upon request

more in accordance with actual weights in institutional investment portfolios. This result could be caused by the inclusion of direct infrastructure. Both, direct real and direct infrastructure returns are positively correlated to each other and both diversify bond returns. However, as direct infrastructure exhibits considerably lower levels of downside risk, it is more heavily weighted than direct real estate. Moreover, the diversification benefits between direct infrastructure and private equity are much more distinctive than those between direct real estate and private equity. Therefore, direct infrastructure seems to partially replace direct real estate in unconditional portfolios. This issue is discussed further in Section VIII. When the target return is low, stocks, commodities and REITs are represented only marginally and disappear from efficient portfolios when the target is set to the highest level. One might argue that the low proportion of stocks stems from their poor performance during the recent financial crisis. However, the allocation to stocks is even smaller when we control for the effects of the crisis and run the optimization from Q2 1990 to Q2 2007.[31]

4.6.2 Bull Market Portfolios

While hardly any equities are present in unconditional portfolios, their importance is apparent in up markets as shown in exhibits 10A and 10B. Due to outstanding performance, high allocations to small caps of between 21% and 54% of total wealth are recommended. They are not only heavy in high return portfolios, but appear across all levels of expected returns. Surprisingly, large caps do not move together with small caps, but even diversify their shortfalls for lower targets. Together with high returns, this induces allocations within a range from 6% to 26%. Although direct real estate returns are negatively correlated with shortfalls of some assets, at least for the first and the second target, it is not accounted for within any efficient bull-market portfolio. This is, on the one hand, due to its low returns, but is also caused by the fact, that other assets feature even better diversification benefits. Direct infrastructure, which yields lower risk-adjusted returns than direct real estate, for three out of four targets, exhibits better diversification benefits with important up-market assets like small caps or commodities. These diversification effects are apparent even for high target rates. As a result, infrastructure increases with rising targets and mounts to a maximum of 28% and constitutes an important asset for low-to-medium-return portfolios across all benchmark returns. Despite its low returns, bonds are allocated to low-return portfolios, as they offer good diversification benefits, in particular with respect to downside returns of small caps, direct infrastructure and commodities. The allocation to commodities is relatively stable across all expected returns, which

[31] The results are available from the authors upon request.

reflects a mix of good performance and diversification effects. Although REITs deliver higher returns, by simultaneously being exposed to lower downside risk than indirect infrastructure, both assets are weighted to a similar extent for targets of 0.0% and 0.5%. This is due to the diversification properties of infrastructure stocks, especially towards small caps. When higher targets have to be achieved, REITs are allocated more heavily.

4.6.3 Bear Market Portfolios

Sortino ratios and downside correlations reveal that an investment in direct real estate yields attractive risk-adjusted returns, along with significant diversification benefits towards bonds and cash in down markets. Therefore, direct real estate contributes essentially to portfolio performance and plays a major role in asset allocation. As exhibits 11A and 11B indicate, relatively high allocations of between 0% and 27%, which clearly exceed the numbers in unconditional models and those in most institutional investment portfolios, are recommended. These high proportions of direct real estate are robust towards a change in the target rate, which indicates that direct real estate is included in the portfolio mainly because of its relatively high returns. Although direct real estate has higher risk-adjusted returns than direct infrastructure, direct infrastructure accounts for a significant proportion, predominantly in low and medium- expected-return portfolios and amounts to a maximum of 52% of total wealth. Together with direct real estate, it exhibits low correlations to bonds, but is more effective in diversifying private equity downside returns. The higher allocation to direct infrastructure is, however, not mainly attributable to better diversification benefits, but rather to the fact that it exhibits much lower downside risk than direct real estate. The distributional characteristics, i.e. positive skewness *and* kurtosis, contribute to these results and indicate a preference for direct infrastructure in a downside risk framework. Bonds diversify direct real estate, as well as direct infrastructure downside returns across all benchmarks. Together with high risk-adjusted returns, this provides a strong rationale for including a large proportion of bonds in down- market states. The theoretical allocations amount to a maximum of 54%. In contrast to direct real estate and infrastructure allocations, bonds are also included in higher-expected-return portfolios, as they exhibit negative correlations with shortfalls of private equity, which is allocated for higher return levels. Stocks, indirect infrastructure and commodities only play a minor role, due to their weak performance and common downward bias in bear markets. Only REITs are included up to a small proportion of 6% for low expected returns and target rates.

Exhibit 9A: Unconditional Portfolio Compositions
Target: 0.0%

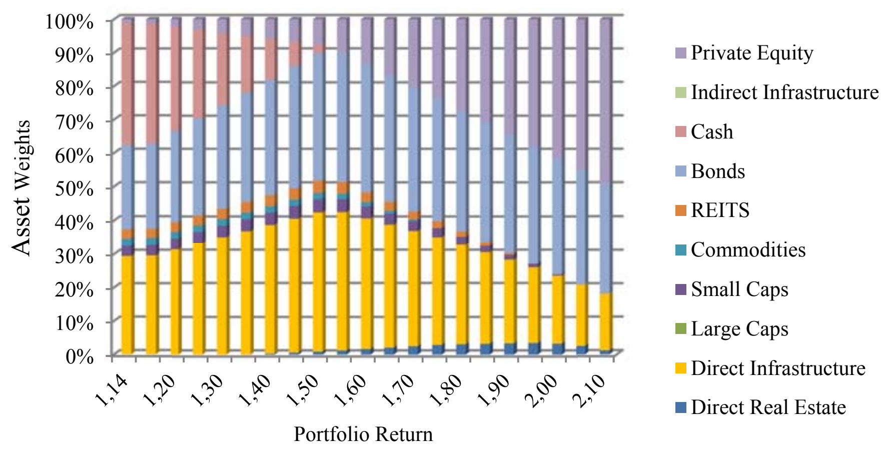


Exhibit 9B: Unconditional Portfolio Compositions
Target: 2.0%

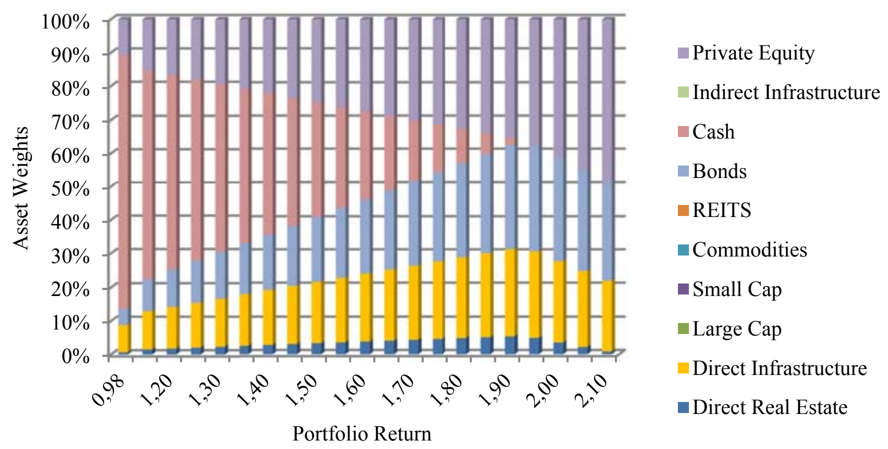


Exhibit 10A: Up Market Portfolio Compositions
Target : 0.0%

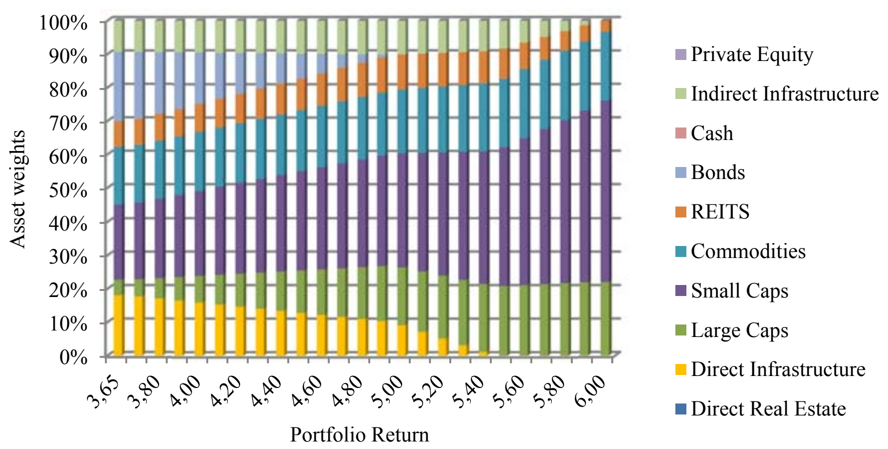


Exhibit 10B: Up Market Portfolio Compositions
Target: 2.0%

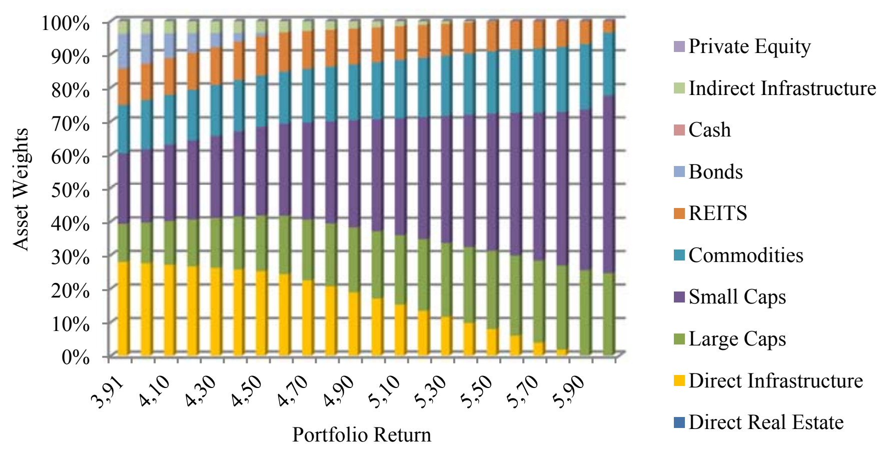


Exhibit 11A: Down Market Portfolio Compositions
Target: 0.0%

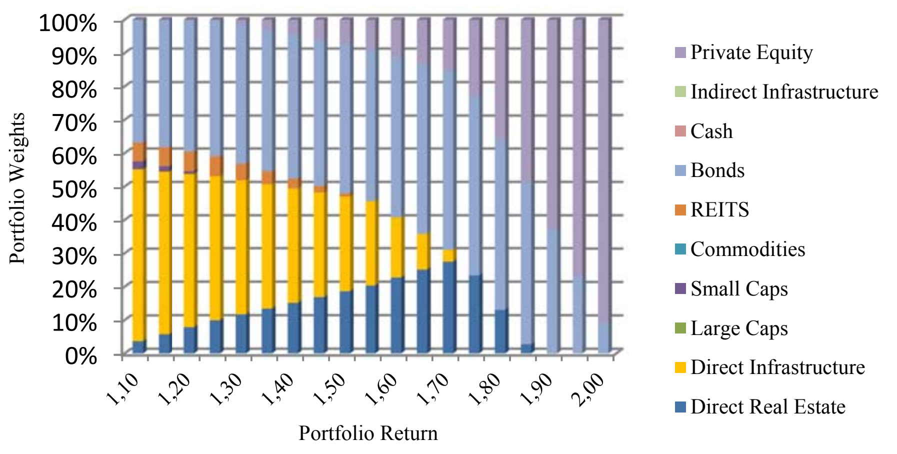
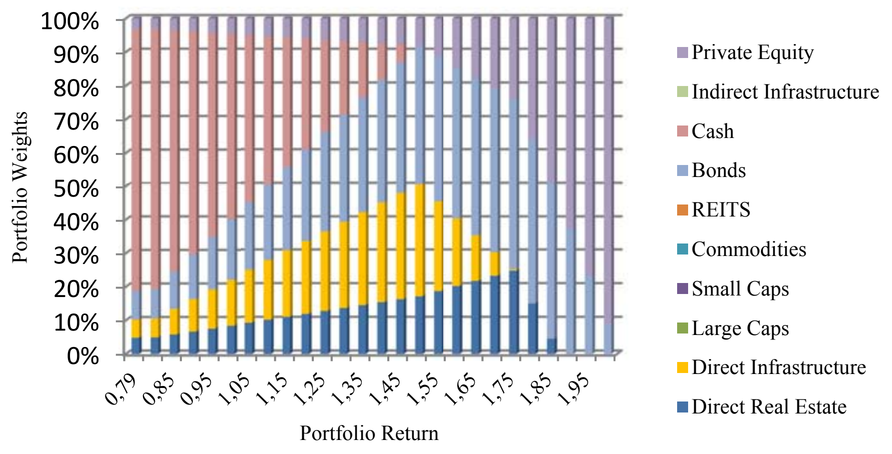


Exhibit 11B: Down Market Portfolio Compositions
Target: 2.0%



4.6.4 Constrained Asset Allocations

The previous results were determined without any restrictions on portfolio weights and constitute theoretical asset weights. In statistical terms, these allocations are corner solutions. However, in practice, many institutional investors like pension funds are – due to regulatory constraints or strategic issues – restricted in terms of their asset allocations and often heavily invested in large cap stocks and bonds. In order to examine the effect and role of direct real estate and direct infrastructure in constrained portfolios, we impose restrictions on the efficient frontiers. The combined allocation to bonds and large cap stocks must sum up to at least 60% with at least 20% of the total wealth being allocated to one of these assets. To be responsive to changing market conditions, many investors hold a proportion of their total wealth in liquid assets which, however, should not exceed a certain percentage. Therefore, we specify the weighting to cash at a minimum of 5% and a maximum 10%.

Exhibits 12A to 14B present constrained portfolio weights in three different market states. As the diversification benefits of direct real estate to large cap stocks are not very distinctive across the whole sample, real estate is removed from the portfolio. Since large caps enter the portfolio, the allocation to direct infrastructure declines for the first and the second target return. However, the allocation remains relatively high with weights up to 35%. For the two higher target returns, the allocation to direct infrastructure increases, due to its diversification benefits with large caps and bonds, as well as from removing cash. While real estate loses its position in unconditional portfolios, infrastructure remains an important asset when asset weights are constrained. Although the inclusion of large cap stocks and bonds induces a reduction of direct infrastructure weights in up markets, infrastructure is still included in the portfolio and allocations amount to a maximum of 15% - again a result of its diversification benefits with bond and stock returns. In down market portfolios, both assets – direct infrastructure and direct real estate – are still heavily weighted and contribute to portfolio diversification as well as to stable returns.

Exhibit 12A: Unconditional Portfolio Compositions Constrained;
Target: 0.0%

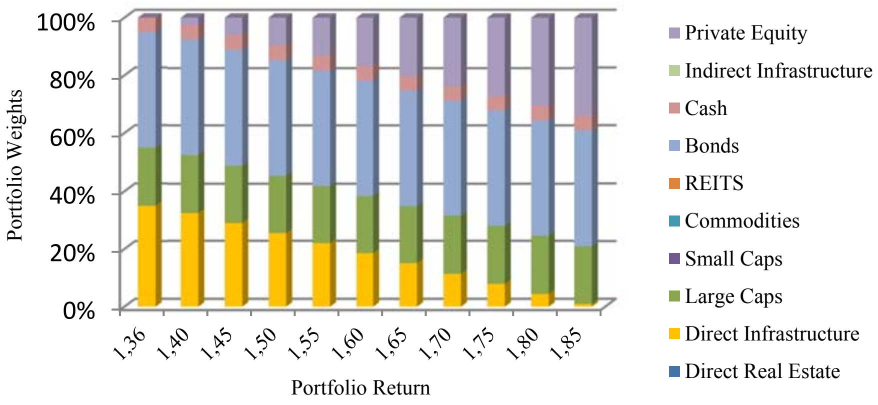


Exhibit 12B: Unconditional Portfolio Compositions Constrained;
Target: 2.0%

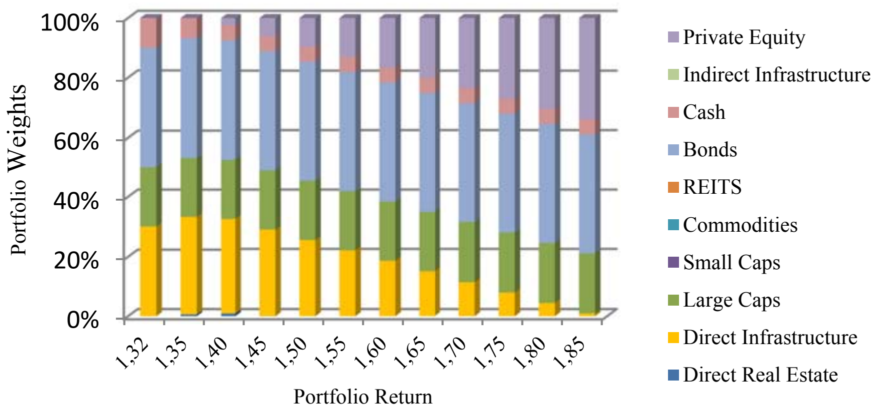


Exhibit 13A: Up Market Portfolio Compositions Constrained;
Target: 0.0%

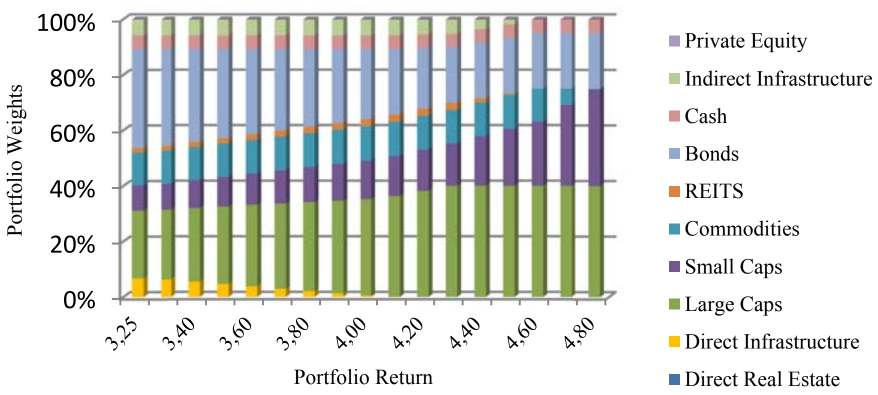
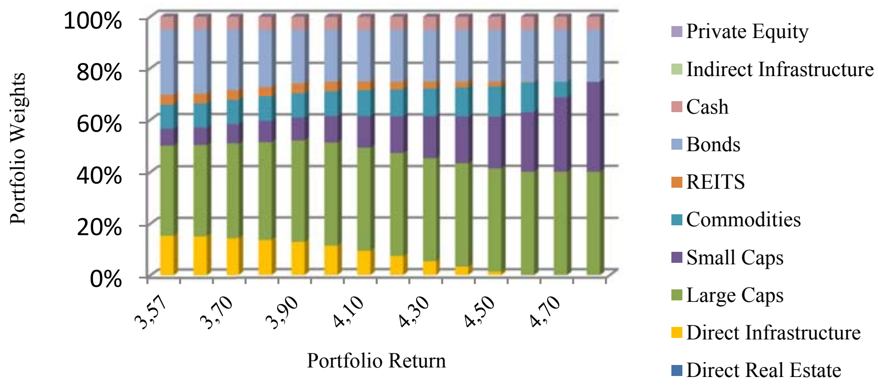


Exhibit 13B: Up Market Portfolio Compositions Constrained;
Target: 2.0%



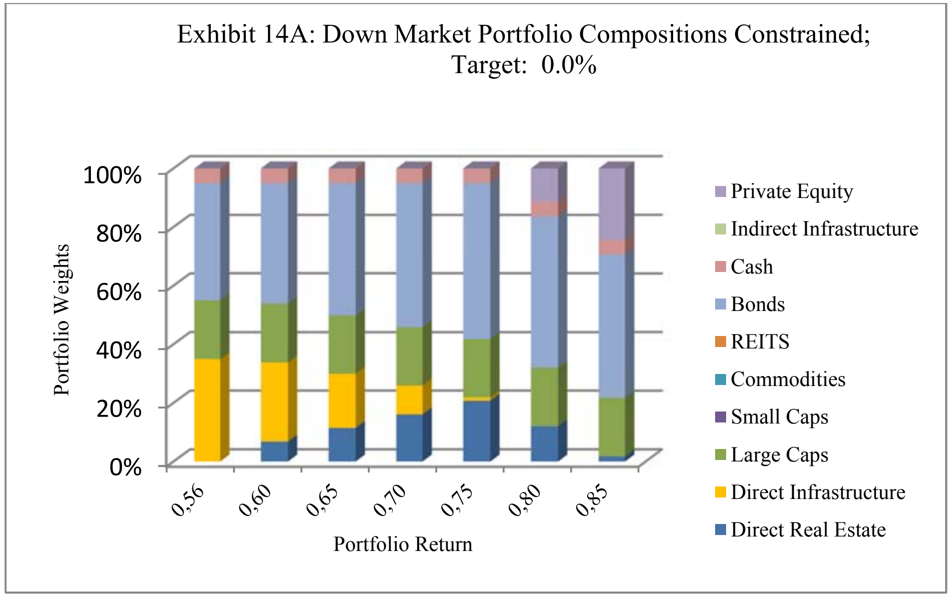


Exhibit 14A: Down Market Portfolio Compositions Constrained;
Target: 0.0%
100%
80%
60%
40%
20%
0%
Portfolio Weights
0,56
0,60
0,65
0,70
0,75
0,80
0,85
Portfolio Return
Private Equity
Indirect Infrastructure
Cash
Bonds
REITS
Commodities
Small Caps
Large Caps
Direct Infrastructure
Direct Real Estate

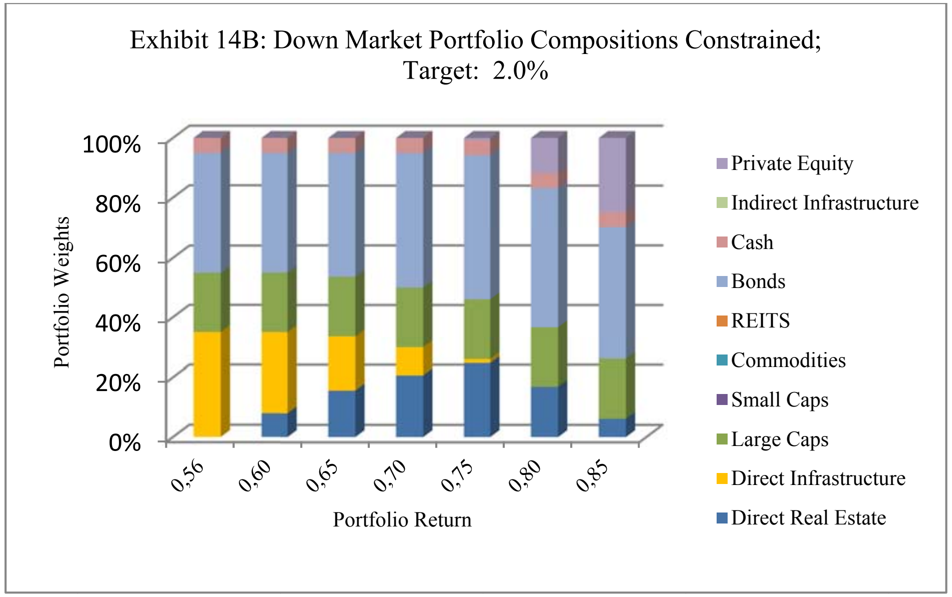


Exhibit 14B: Down Market Portfolio Compositions Constrained;
Target: 2.0%
100%
80%
60%
40%
20%
0%
Portfolio Weights
0,56
0,60
0,65
0,70
0,75
0,80
0,85
Portfolio Return
Private Equity
Indirect Infrastructure
Cash
Bonds
REITS
Commodities
Small Caps
Large Caps
Direct Infrastructure
Direct Real Estate

4.7 The Effects of Infrastructure on Asset Weights

4.7.1 Unconditional Portfolios

In order to gain an impression of the extent to which the inclusion of direct and indirect infrastructure[8] affects the allocation to other assets, in particular real estate, unconditional and conditional efficient portfolios are estimated with and without infrastructure assets. As exhibits 15A and 15B reveal, the inclusion of direct infrastructure to unconditional multi-asset portfolios significantly impacts on the allocations to direct real estate, cash and private equity, by inducing a reduction in the proportion of these assets. As direct infrastructure is, similar to cash, perceived as a low-risk, low-return asset, and exhibits characteristics common to direct real estate, these changes in asset allocations make sense intuitively. Portfolios without infrastructure comprise direct real estate up to a maximum of 25%. This allocation, however, decreases down to a maximum of 7%. The effect that direct real is replaced by direct infrastructure is consistent across all examined target returns. Although direct real estate outperforms direct infrastructure in unconditional market states, there are several reasons why the allocation to direct real estate diminishes when infrastructure is added to the portfolio. One reason is that direct infrastructure investments exhibit lower levels of downside risk. Furthermore, as a consequence of its positively skewed returns, direct infrastructure more effectively diversifies downside returns from other assets. Moreover, downside returns from infrastructure can more easily be diversified than those from real estate. As the downside returns of both assets are, moreover, positively correlated, direct infrastructure usurps the position that real estate occupied before the inclusion of infrastructure. While other studies find no asset that provides such unique diversification benefits as direct real estate, direct infrastructure does indeed seem to do so and additionally provides attractive risk-adjusted returns. Although our results suggest a need to remove funds from direct real estate and allocate them to direct infrastructure, one has to bear in mind that actual direct real estate allocations are not as high as suggested by the model, but significantly lower. Therefore, these results do not automatically imply that investors should replace real estate with infrastructure, but investors might reconsider their portfolio allocations, so as to obtain a better risk return tradeoff through the inclusion of infrastructure. In terms of theoretical portfolio allocations, these results imply that the allocation to direct real estate and cash might be overstated, when direct infrastructure is not considered in an asset allocation framework. As a further result, one can easily see that direct infrastructure removes a significant proportion of cash from the portfolio. This occurs, as infrastructure significantly outperforms cash by contemporaneously offering relatively low levels of downside risk. However, cash returns are negatively correlated to most other assets and cash, furthermore, exhibits the lowest downside risk of all analyzed investment opportunities. Therefore, allocations to this asset class remain fairly high, especially for low-to-medium-expected-return portfolios. For higher expected returns, cash is replaced almost entirely by direct infrastructure. Private equity is replaced by direct infrastructure in low-return portfolios, which stems from direct infrastructure's diversification effects with bonds. This does not hold for higher expected-return portfolios, as private equity returns are required to achieve these returns. In contrast to the common belief that infrastructure assets show some bond-type characteristics, as stable and predictable cash flows, the allocation to bonds is not very heavily affected by the inclusion of direct infrastructure. As a result of higher average infrastructure returns, bonds lose weight for higher-expected-return portfolios. However, since bonds and direct infrastructure diversify each other for lower target returns, the allocation to bonds even increases in low-return portfolios when direct infrastructure is allowed to enter the portfolio. A similar argumentation applies to REITs, whose allocations increase slightly with the inclusion of infrastructure. Their downside returns are also negatively correlated to indirect infrastructure performance.

4.7.2 Bull Market Portfolios

Although infrastructure is regarded as a low-risk, low return investment, it is present in up-market portfolios and predominantly replaces bonds, which lose weight for each target rate (see Exhibit 16A and 16B). Furthermore, one can observe that private equity investments are eliminated from the portfolio. As direct real estate is not present in up-market portfolios, the inclusion of infrastructure cannot affect its allocation. However, REITs lose weight when direct and indirect infrastructure enters the portfolio. This is mostly due to the inclusion of indirect rather than direct infrastructure and mostly happens for smaller targets. At a first glance, there seems to be no reason why infrastructure should replace private equity. Private equity exhibits higher average returns and lower downside risk than direct and indirect infrastructure investments. Moreover, neither direct nor indirect infrastructure diversifies downside returns on most other assets more effectively than private equity. However, the ability of other assets to diversify direct and indirect infrastructure downside returns is much more distinctive than diversifying downside returns on private equity. The loss in return which results from the exclusion of private equity is offset by the inclusion of small caps, which exhibit the best performance in up markets. The higher downside risk of small caps is tolerated, as small caps exhibit more attractive diversification properties with (direct) infrastructure than with private equity. This explains the switch in allocations from private equity to infrastructure assets and to small caps in up markets. As infrastructure assets have higher risk-adjusted returns than bonds and also offer attractive diversification benefits with stocks, the explanation of the decrease in bond weights is straightforward. The reason for the exclusion of private equity and bonds is due mainly to the inclusion of direct infrastructure rather than indirect infrastructure assets.

4.7.3 Bear Market Portfolios

Although, the inclusion of direct infrastructure also leads to a decrease in direct real estate weights in down markets, these effects are not as distinctive as those found for unconditional portfolios (see Exhibit 17A and 17B). Although direct infrastructure is more effective in terms of diversification, it offers a lower level of downside risk and is positively related to downside real estate returns across all target rates. Direct real estate is still heavily weighted and its allocation is above those in most institutional investment portfolios. This stems mostly from the superior performance of direct real estate in down markets, which is significantly above that of infrastructure. The negative correlation with bonds, which is the dominant asset in down markets, is a further reason for the relatively high direct real estate weights.

Contrary to intuition, the inclusion of direct infrastructure enhances the proportion of bonds in the portfolio for the two lower-benchmark returns and for low expected returns. Due to the negative correlations between both assets, this comes as no surprise.

For lower target rates and lower expected returns, the inclusion of infrastructure raises the proportion of REITs in the portfolio. Although this also sounds somewhat counterintuitive, this stems from the fact that direct infrastructure investments diversify down movements in REIT returns and vice versa. Similar to unconditional portfolios, cash is removed from the portfolio.

Exhibit 15A: Effect of Infrastructure on Unconditional Asset Weights; Target: 0.0%

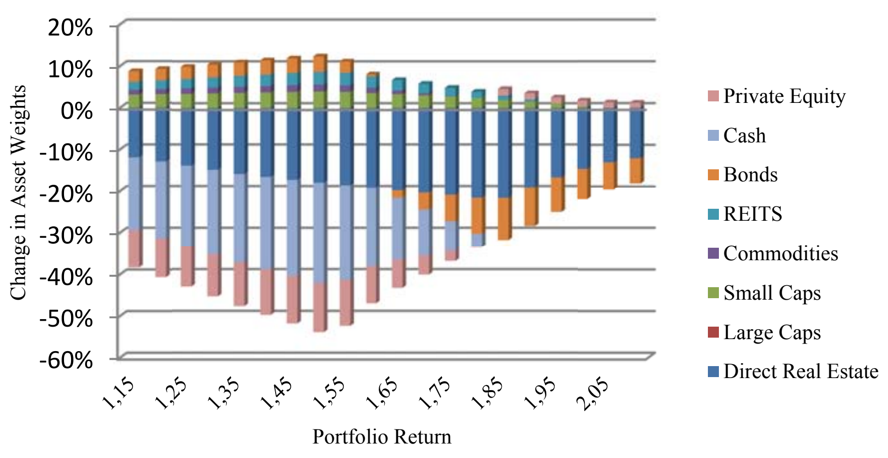


Exhibit 15B: Effect of Infrastructure on Unconditional Asset Weights; Target: 2.0%

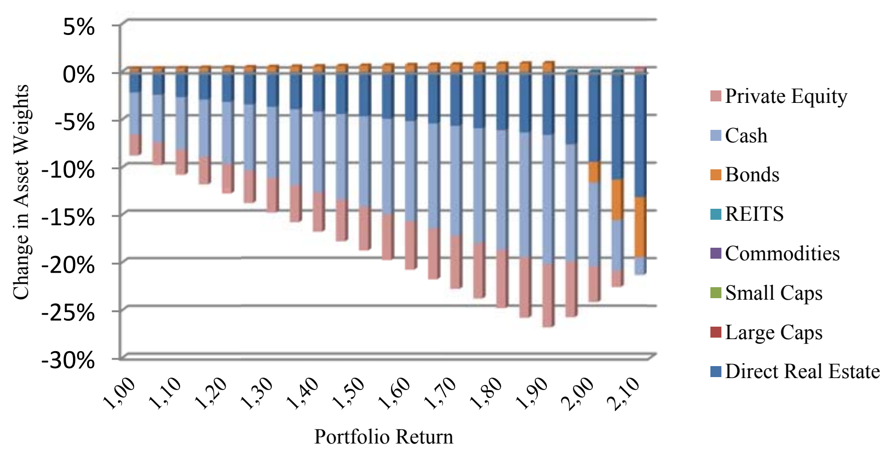


Exhibit 16A: Effect of Infrastructrue on Asset Weights Up Markets; Target: 0.0%

Exhibit 16B: Effect of Infrastructure on Asset Weights Up Markets; Target: 2.0%

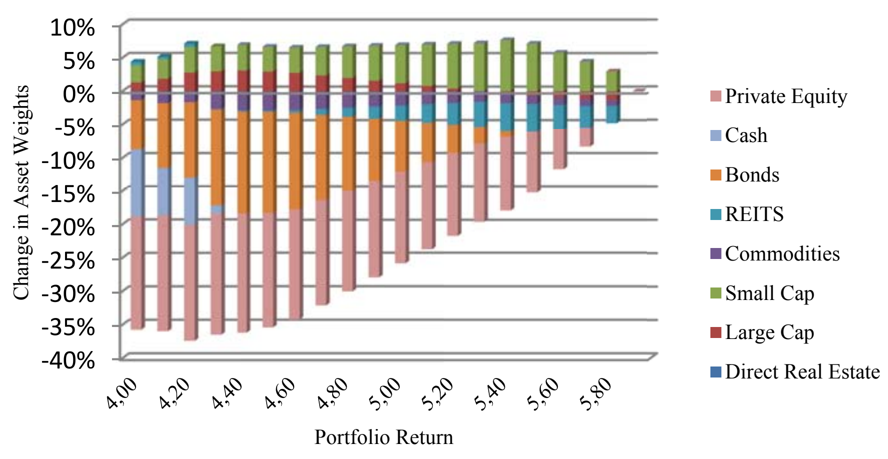


Exhibit 17A: Effect of Infrastructure on Asset Weights Down Markets; Target: 0.0%

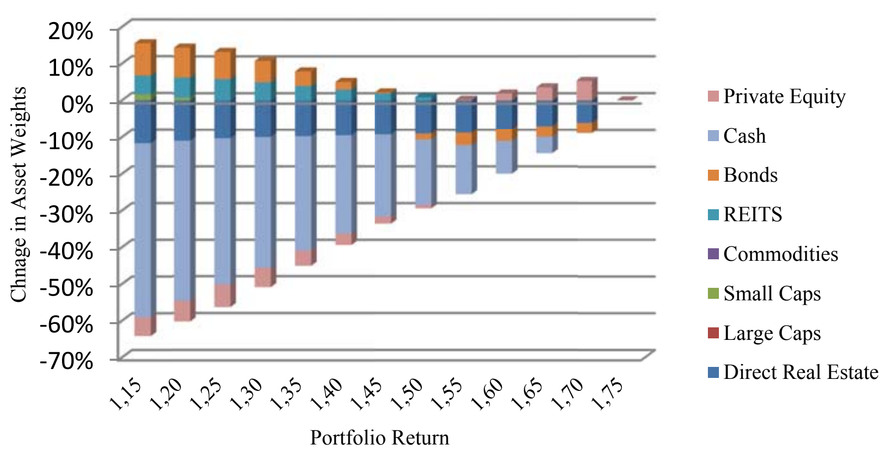
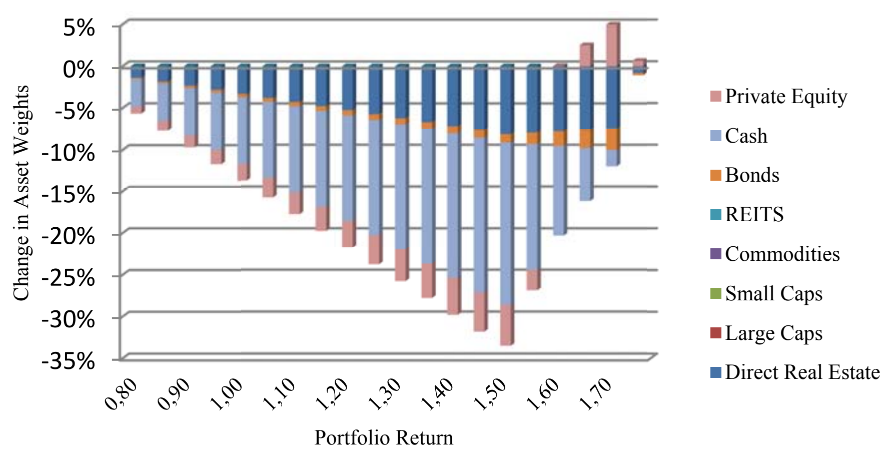


Exhibit 17B: Effect of Infrastructure on Asset Weights Down Markets; Target: 2.0%



4.8 Conclusion

The emergence of infrastructure as an asset class requires a reassessment of traditional portfolio strategies, which are based mainly on assets like stocks, bonds and real estate. This study addresses the issue by using a novel data set on individual infrastructure cash flows which facilitates – for the first time – building a direct infrastructure total return index. We determine efficient portfolio weights when infrastructure and real estate are allocated simultaneously to a multi-asset portfolio that contains a range of further assets. We focus in particular, on the relationship between real estate and infrastructure as these assets are often assumed to exhibit similar underlying characteristics and similar diversification benefits.

Since the role of downside risk is intuitive and evident in the pricing of risky assets, we apply an optimization algorithm which accounts for a measure of downside risk, rather than of variance. This approach is likely to conform more closely to rational investor behavior and is capable of reflecting different target returns. In order to account for time-varying asset behavior, we draw a distinction between up and down markets and determine dynamic portfolio weights.

Two general results can be summarized as follows. Firstly, attributable to the time-varying return characteristics of various assets, the composition of efficient portfolios is heavily dependent on the state of the market. Secondly, asset allocations differ significantly with a change in investor-specific target return. Ignoring these issues may lead to results of only limited significance.

In terms of direct real estate portfolio weights, the unconditional models produce allocations which are more in accordance with the practice of institutional investment portfolios, but below the allocations in most other asset allocation studies. This result is caused mainly by two factors. Firstly, employing downside risk instead of variance is more appropriate when asset returns are not normally distributed. As direct real estate returns are characterized by high kurtosis, this is accounted for in the downside-risk approach. Furthermore, the inclusion of a broad range of investment opportunities is likely to avoid allocations which are too heavy in one asset. Unconditional results in particular, reveal the importance of direct infrastructure for portfolio diversification and show that theoretical allocations to direct real estate are likely to be overestimated when direct infrastructure is not considered. The allocation to real estate is significantly higher when infrastructure assets are not accounted for. This effect is mostly evident in unconditional portfolios and a result of similar returns and infrastructure's diversification benefits as well as its lower downside risk.

The important role of direct real estate is apparent in a conditional allocation framework. While equities – including infrastructure stocks – commodities, REITs and direct infrastructure are the predominant assets in up markets, direct real estate performs well in bear markets and is helpful in diversifying downside returns from other assets. As a result, the recommended allocations rise to a maximum of 27%. These high proportions hold across all target rates. Although the allocation to direct real estate also suffers in down markets when infrastructure is included, this effect is not as distinctive as in unconditional market states. This is caused mainly by relatively high direct real-estate returns in down markets, which significantly exceed those from direct infrastructure. Nevertheless, direct infrastructure is weighted more heavily than direct real estate, as it also provides diversification benefits and exhibits a low level of downside risk when stock markets perform badly. However, it is more sensitive towards changes in the benchmark return than direct real estate. According to these findings, *both* assets, direct real estate and direct infrastructure add substantial value to portfolios in bear markets. Real estate does so mainly due to its high returns and infrastructure due to its diversification benefits. These results throw new light on the role of real estate in the asset allocation process and highlight the importance of the market state for portfolio compositions. Efficient allocations are dependent on numerous parameters and no strict proportion of assets proves to be consistently superior. However, as transferring direct real estate and direct infrastructure assets evokes significant transaction costs and is associated with a high expenditure of time, the adjustment of portfolio weights creates enormous difficulties. Therefore, when direct assets are considered within a time-varying allocation framework, the results must be interpreted with caution. It makes no sense for investors to change their allocation in accordance with their expectation[1] of market moves, but direct real estate, as well as direct infrastructure, constitute important assets when the main concern is to protect the portfolio in downside markets and when investors are prepared to relinquish some return in order to achieve this aim. An investor who is interested mainly in participating in market upswings is recommended to invest in equities and indirect, rather than direct real estate. As direct infrastructure also constitutes an important component in bull markets, our results point to a significant allocation to direct infrastructure investments. However, one has to consider that, the allocation to direct infrastructure in particular is highly sensitive to a change in the target rate, as it is included in the portfolio mainly due to its diversification benefits, rather than to its outstanding returns. Considering the fact that infrastructure accounts for a significant proportion of GDP and considerating our results, an investor is exposed to non-systematic risk, if

[1] Moreover, the investor has to anticipate the state of the market ex ante.

direct infrastructure is not included in the investment portfolio. However, neither infrastructure nor any other alternative asset is able to replace real estate in institutional investment portfolios as a whole. Although the allocation to direct real estate is below the findings in other asset allocation studies, the importance of direct real estate is evident. Especially in down markets, there is no other asset which delivers such high returns, while providing similar diversification benefits.

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5. How much into Infrastructure? Evidence from Dynamic Asset Allocation

Tobias Dechant Konrad Finkenzeller

Abstract

This paper investigates the role of direct infrastructure investments in a multi-asset portfolio, by employing a US transaction-based index which covers the period Q2 1990 to Q2 2010. We determine time-varying asset allocations using a mean-variance, as well as a mean-downside risk optimization algorithm and show that infrastructure plays an important role in both models. It is allocated predominantly to portfolios that exhibit low-to-medium risk with maximum allocations of 32% and 28%, respectively. With increasing investment horizons, infrastructure is also attractive to investors who aim at earning higher returns, and especially to those who wish to protect low - expected - return portfolios from downside risk. As infrastructure and large cap stocks are highly correlated over longer investment horizons, the allocation to infrastructure is sensitive to whether large cap stocks are allocated to the portfolio. Furthermore, we find that infrastructure is not a substitute for real estate.

5.1 Introduction

Direct Infrastructure[1] investments have become increasingly important for investors in recent years and private transaction volumes are estimated to be about $250 billion globally in 2010 (Mahmudova et. al., 2011). Australian and Canadian pension schemes, in particular, constitute pioneers in this sector and already hold infrastructure shares of up to 15 percent of total wealth in their portfolios (Inderst, 2009).

There is general consensus on the economic significance of infrastructure as a driver of economic growth, productivity and competitiveness and this is well documented in the macroeconomic literature (Röller and Wavermann, 2001). However, the provision of adequate infrastructure facilities throughout the world is currently jeopardized by financial strains on governments, causing underinvestment, inadequate replacement and poor maintenance. Emerging markets, on the other hand, are forced to synchronize infrastructure provision in tandem with their high economic growth rates in order to foster sustainable growth and global competitiveness. This situation creates an imbalance between the demand and supply for infrastructure assets. According to the OECD (2006, 2007), global infrastructure requirements are estimated at about US$ 3 trillion p.a., while governments are only able to cover US$ 1 trillion – a situation which could induce the rapid growth of private investment opportunities in the ensuing years.

Investor demand for infrastructure assets is driven primarily by certain main attributes which are in accordance with the requirements of many (institutional) investors. The long investment horizons match their long-term liabilities and the inelastic demand for infrastructure services implies steady and inflation-hedged cash flows. Most importantly, the unique risk-return characteristics of infrastructure assets are intended to supplement new sources of diversification towards traditional assets like stocks, bonds and real estate. Therefore, investors are beginning to perceive infrastructure as a separate asset class, thus establishing specific infrastructure allocation targets and concomitantly removing infrastructure from their private equity or real estate portfolios.

However, the underlying market for direct infrastructure investments is rather opaque and inefficient, and still lacks professional structures such as efficient secondary markets and experienced market participants. A further issue with infrastructure investments is the limited

[1] Infrastructure assets can be divided into two main categories: economic and social infrastructure. Economic infrastructure includes long-lasting, large-scale physical structures like transportation and communication infrastructure, as well as energy and utility facilities. Social infrastructure, on the other hand, includes education, healthcare, waste disposal as well as judicial facilities (Wagenvoort et al.2010). The infrastructure investment universe is accessible via direct physical acquisitions of the asset/ the user rights or via several forms of securitized infrastructure, such as closed-ended private equity funds, as well as listed infrastructure companies.

availability of direct performance data, which also impedes academic research. Consequently, only a few studies investigate the role of infrastructure in investment portfolios and the related academic literature is dominated by research dealing with listed infrastructure data. This paper contributes to the existing literature by investigating whether direct infrastructure can contribute to portfolio performance and diversification, and how much infrastructure should be allocated to investment portfolios. Employing a transaction-based infrastructure index, we estimate time-varying allocations to infrastructure, using two different optimization algorithms. We first employ a simple mean-variance (MV) procedure. Secondly, to account for the non-normal distribution of various asset returns, we employ a mean-downside risk (MDR) algorithm. Downside risk (DR) is a more intuitive measure of risk, as it only accounts for shortfalls below a pre-defined target rate of return. The dynamic optimization procedure enables accounting for time-varying asset characteristics and therefore delivers more robust allocations than a static optimization procedure, which yields only one value for each asset in an efficient portfolio.

Our results indicate that infrastructure plays an important role in both mean-variance and in mean-downside risk efficient portfolios. Infrastructure is allocated predominantly to portfolios that exhibit low-to-medium risk with maximum allocations of 32% and 28%, respectively. With increasing investment horizons, infrastructure is also attractive to investors who aim at higher returns, and especially to those who wish to protect low-expected-return portfolios from downside risk. Due to the similar underlying characteristics of large cap stocks and infrastructure, both assets exhibit significant positive correlations over longer investment horizons. If the share of large cap stocks is fixed and sufficiently high, this induces a significant decrease in the proportion of infrastructure. Furthermore, we present evidence that infrastructure is no substitute for real estate.

The remainder of this paper is structured as follows. The next section reviews the literature on infrastructure asset allocation. Section 3 introduces the employed data. The applied methodology is explained in detail in part 4, and some descriptive statistics are presented in part 5. The paper continues with a description and discussion of the results. The final section concludes.

5.2 Literature Review

Research on infrastructure asset allocation is mainly industry driven (see for example Mansour and Nadji (2007) as well as, Idzorek and Armstrong (2009)). Due to a lack of direct performance data, academic research is still in its infancy and mostly based on listed asset performance.

Bond, Hwang, Mitchell, and Satchell (2007) employ the Macquarie Global Infrastructure Index over the period 1997 to 2006 and show that no alternative asset class, such as commodities, hedge funds or indirect infrastructure, provides a significant level of risk reduction, when allocated to a portfolio of UK core assets. Newell and Peng (2008) use the entire UBS US-Infrastructure and utility index series, including different infrastructure sub-sectors, to further analyze the risk adjusted performance and portfolio diversification benefits of listed infrastructure in the US over the period 2000 to 2006. They highlight the outstanding performance and significant diversification benefits from 2003 onwards. Newell, Chau and Wong (2008) conduct the first academic work on infrastructure performance in China, by constructing a listed infrastructure series for Hong Kong and China which covers the period from 1995 to 2006. They find that infrastructure delivers attractive risk-adjusted returns, but they also mention decreasing diversification benefits over time. They further find strong and effective linkages between listed infrastructure and listed commercial property markets. For the Indian market, Singhal, Newell and Nguyen (2011) show that listed Indian infrastructure has high risk-adjusted returns, compared to other infrastructure sectors in the Asia-Pacific region, and compared to general Indian and global stock markets.

The second group of literature enlarges the focus on listed infrastructure by incorporating direct historical performance data. Peng and Newell (2007) investigate the risk adjusted performance and portfolio-diversification benefits of Australian listed infrastructure funds, listed infrastructure companies and unlisted infrastructure funds over the eleven year period from 1995 to 2006. They show that infrastructure contributes to investment portfolios by generating the highest return, but also exhibits high volatility. They additionally present evidence of increasing correlations between unlisted infrastructure and property returns over time. Portfolio diversification benefits from the infrastructure sector however, were confined, particularly with unlisted infrastructure. Finkenzeller, Dechant and Schäfers (2010) employ a sample of major unlisted Australian infrastructure funds to mirror direct infrastructure performance over the Q4 1990 to Q1 2009 horizon. By using a downside risk approach, their results confirm the diversification benefits of direct infrastructure and reveal heavy theoretical portfolio weights for low to medium expected returns. When expected returns increase, indirect infrastructure is allocated to a greater extent to the portfolio. The equal infrastructure dataset is used by Newell, Peng and DeFrancesco (2011) over the period Q3 1995 to Q2 2009. They apply a simple risk/return and correlation analysis and provide some additional insights in regards to the performance of direct and indirect infrastructure during the financial crisis. They report direct infrastructure to be a strongly performing asset on a risk adjusted basis as well as providing significant diversification benefits towards major asset classes both also holding for the recent financial crisis. Based on a US dataset including a broad set of alternatives, Dechant, Finkenzeller and Schäfers (2010) investigate the role of direct infrastructure in a multi asset portfolio by using a professionally constructed US-transaction based infrastructure index. Their analysis underpins the significance of direct infrastructure for portfolio diversification in a downside risk framework and accounts for different states of the market. The findings show that direct infrastructure exhibits a unique asset behavior and optimal allocations are estimated to be between 0% and 27% dependent on return expectations and different market states. Moreover, the authors underline the importance and attractive performance of infrastructure in bear markets.

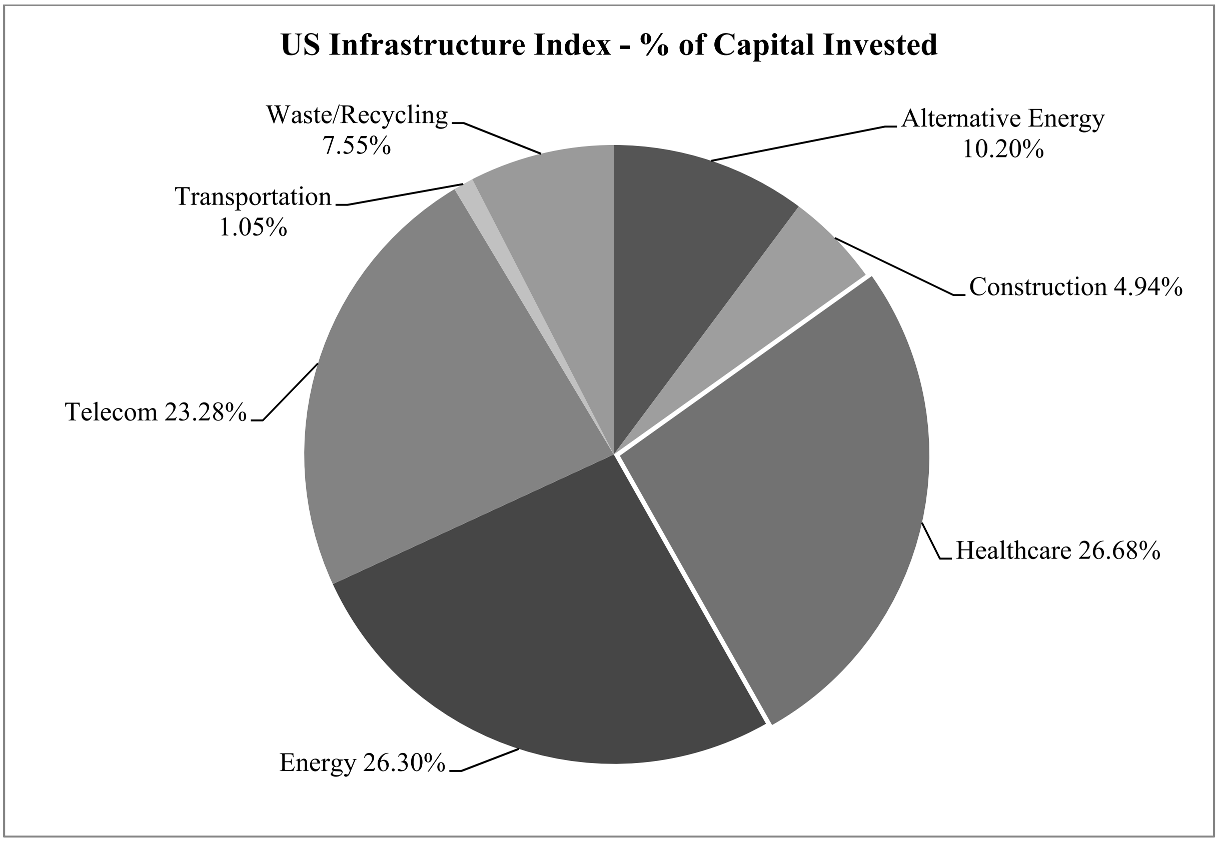
5.3 Data

We employ quarterly US total return data from nine different asset classes, which are deflated by the consumer price index. In particular, we consider direct real estate, direct infrastructure, large cap stocks, small cap stocks, cash, long-term government bonds, long-term corporate bonds, as well as short-term government bonds and short term corporate bonds. The index history covers the period from Q2 1990 to Q2 2010.

The TBI Index, which is published by the MIT center for Real Estate is applied to illustrate direct real estate performance. The direct infrastructure performance index is provided by the Center of Private Equity Research (CEPRES) and is a sub-index of a more general CEPRES dataset of private equity investments, which is used in studies including Krohmer, Lauterbach and Calanog (2009), Franzoni, Nowak and Phalippou (2011) and Füss and Schweizer (2011). The specific infrastructure data/data series is employed by Bitsch, Buchner and Kaserer (2010), Dechant et al. (2011) and Finkenzeller and Fleischmann (2011).The infrastructure index covers a sample of 930 individual operating infrastructure projects in the US and is based on a broad reporting sample of 135 global infrastructure equity investors. The index methodology is in accordance with Peng (2001) and is based on the Method of Moment Repeat Sales Regression (MM-RSR). For a more formal illustration of this process, refer to Schmidt and Ott (2006).

In order to obtain unbiased direct infrastructure performance, the index is corrected for gearing. The capitalization of the index adds up to around $27.2 billion of invested equity and only includes sectors which correspond with the definition of infrastructure from Kaserer et al. (2009). Figure 1 shows the average sector weights, which are calculated according to capital invested over the entire sample period. The relatively high weights of health care, energy and telecom assets are in accordance with the investment objectives of various investors and reflect the weights of institutional infrastructure investments. The average index shares are 34% for social (health care, waste/recycling) and 66% for economic (transportation, telecom, energy, alternative energy, construction) infrastructure. Together with a sufficient number of transactions (930) and a high market capitalization, the index constitutes an appropriate tool for benchmarking direct infrastructure performance in the US.

Figure 1: Infrastructure Index Sector Weights



All remaining assets are sourced from Thomson Datastream. The FTSE US Large Cap index represents large cap stock returns, whereas the S&P 600 Small Cap index proxies returns from equities with a low market capitalization. An investment in cash is represented by the JP Morgan US 3 month cash index. The City CGBI World Government Bond Index United States 10+ reflects the performance of long-term US government bonds, whereas the CGBI World Government Bond Index United States 1-5 years is used to proxy short term government bond performance. Analogously, two corporate bond indices are employed. The Citigroup US Corporate Bond Index AAA / AA 10+ represents long term corporate bond performance and the Citigroup US Corporate Bond Index AAA / AA 1-5 Years represents returns on short term corporate bonds.

Contrary to trading most financial assets, buying and selling direct real estate and direct infrastructure evokes high transaction costs, which reduces return. Round trip costs of 6%[2] are employed for US real estate transactions. Infrastructure transaction costs are, to a large extent, independent of the size of the project, since they all require general services like technical, legal and financial advisory, as well as a sound estimation of demand risk. Moreover, opaque market structures, along with low levels of information efficiency result in high information and due-diligence costs. Therefore, gross transaction costs for all initial project participants can amount to more than 10% of total project value (Dudkin and Välilä (2005), Salino and de Santos (2008)). From a private investor's point of view, average direct infrastructure investments evoke round trip costs of about 7.5%[3]. However, actual transaction costs depend on the holding period of assets. Based on the findings of Kaserer, Buchner, Schmidt and Krohmer (2009), the average duration of infrastructure investments is four years, which seems very short for direct infrastructure investments. However, one has to consider that there is a huge difference between the average concession period which is agreed between the government and the SPV (special purpose vehicle) and the holding period of an individual equity investor. While the concession period agreed between the regulator and the SPV is around 30 years across all sectors, on average, an individual investor might have shorter holding periods, depending on strategic issues, such as the stage of the infrastructure project (Araújo and Sutherland, 2010). Due to the growing maturity of the market and the increasing involvement of long-term investors, the average investment period is likely to rise over the next years. We use the information from Kaserer et al. (2009) to adjust infrastructure returns and to compare real estate returns for a holding period of four years.

5.4 Methodology

We employ two different algorithms for portfolio construction. Firstly, we conduct a mean-variance optimization which is based on the portfolio theory of Markowitz (1952). Secondly, we employ a mean-downside risk optimization which is based on Estrada (2008). Downside risk is a more intuitive measure of risk than variance, as it accounts only for return deviations below a pre-specified target rate and considers the non-normal distribution of asset returns. Using the Estrada methodology has the advantage that it creates a symmetrical and exogenous co-lower partial moment (CLPM) matrix.

[2] We thank David Geltner for providing this information.
[3] We thank various institutional infrastructure investors and consultants for providing this information.

Formally, the Markowitz-optimization can be written as follows:

Minimize

$$\sum_{i=1}^{N}\sum_{j=1}^{N} x_i x_j \sigma_{ij} \tag{1}$$

Subject to

$$\sum_{i=1}^{N} x_i \bar{r}_i = \bar{r}_p$$

$$\sum_{i=1}^{N} x_i = 1$$

$$x_i \geq 0$$

$$i = 1,2,\ldots,N$$

Where

x_i = the proportion of the portfolio allocated to asset i

$\bar{r}_p$ = the expected portfolio return

$\bar{r}_i$ = the expected return on asset i

σ_{ij} = the covariance between asset i and asset j

We employ the lower partial moment (LPM) as a measure of downside risk. This is defined as follows:

$$LPM_n = \int_{-\infty}^{b} (b - r_i)^n \, df(r_i) \tag{2}$$

Where b is an investor-specific target rate of return, n is the parameter of risk-aversion and r_i is the return on asset i which follows the distribution $f(r_i)$.

Downside risk optimization is given by:

Minimize

$$\sum_{i=1}^{N} \sum_{j=1}^{N} x_i x_j \varphi_{ij} \tag{3}$$

Subject to

$$\sum_{i=1}^{N} x_i \overline{r_i} = \overline{r_p}$$

$$\sum_{i=1}^{N} x_i = 1$$

$$x_i \geq 0$$

$$i = 1, 2, \dots, N$$

Where

φ_{ij} = the CLPM between asset i and asset j which is given by

$$\varphi_{ij} = \frac{1}{N}\sum_{t=1}^{N} Min(r_i - b, 0)\, Min(r_j - b, 0) \tag{4}$$

To account for time variation in the covariance and in the CLPM, we employ a dynamic asset allocation procedure. This means that we form ten efficient portfolios at each point in time (each quarter), by using observations from the past 48 quarters. The ten estimated portfolios comprise the minimum-risk[4] portfolio (portfolio 1) and the maximum return portfolio (portfolio 10), as well as the eight portfolios in between. The distance between the expected portfolio return on the ten portfolios is equal for each separate point in time. In order to match our model with the actual holding period of infrastructure assets in the market, we assume a holding period of four years and calculate transactions costs correspondingly. As a result of the investment period and the 48 period rolling window, we obtain the initial efficient portfolios in Q1 2006. After each optimization, we roll forward one quarter and again perform the optimization. This results in a time series of portfolio allocations for each of the ten portfolios. The rolling optimization procedure enables accounting for changing asset characteristics over time and delivers more meaningful results than a static optimization procedure, which yields only one value for each asset in the portfolio. In the downside risk optimization, we employ a target of 6% real return[5] per annum, which implies that only outcomes below this target rate constitute a risk to an investor, and only these outcomes are employed to calculate the LPM and the CLPM. Although this number seems to be very high in comparison to other asset allocation studies, one has to bear in mind that we assume a holding period of four years, which makes it more realistic that a certain target rate is met, on average. In summary, our base-model employs 48 quarters of data for optimization and assumes a holding period of four years. Furthermore, the downside-risk approach is conducted with an annual target return of 6% real return.

[4] This is the minimum variance portfolios (MVP) and minimum downside risk portfolio (MDP).

[5] Many asset allocation studies employ the risk-free rate of return or zero as a benchmark return. However, this definition only makes sense for shorter investment horizons, because it is clear that assets which are riskier than the risk-free rate are likely to produce higher returns over greater investment horizons. Because we employ an investment horizon of four years, only a very few return are situated below that of the risk-free rate. This results in a reduced number of data for the calculation of the CLPM, which makes the results less reliable and dependent on extreme outliers. For this reason, the risk-free rate is not employed as a benchmark return. A target return of zero tightens this problem and does not even allow for calculating the portfolio LPM.

In reality, the characteristics of infrastructure and real estate assets entail a construction and/or an implementation lag. However, our infrastructure and real estate data are based on conservative brownfield/core assets, which deliver available operating cash-flows and do not involve planning and/or construction periods. One might argue that the implementation of infrastructure/real estate assets demands a time-intensive due diligence process which depends on such parameters as project type, size, etc. However, the quarterly observation frequency of our analysis should, on average, be able to cover this phase for the majority of projects. Furthermore, we assume a holding period of four years so that implementation is a minor problem. Moreover, the main focus of the study is not on comparing different portfolio strategies in terms of the risk, return and timing of implementation, but to construct efficient combinations of assets, based on the information available at each point in time. Furthermore, illiquidity is (at least partially) accounted for by transaction costs.

5.5 Descriptive Statistics

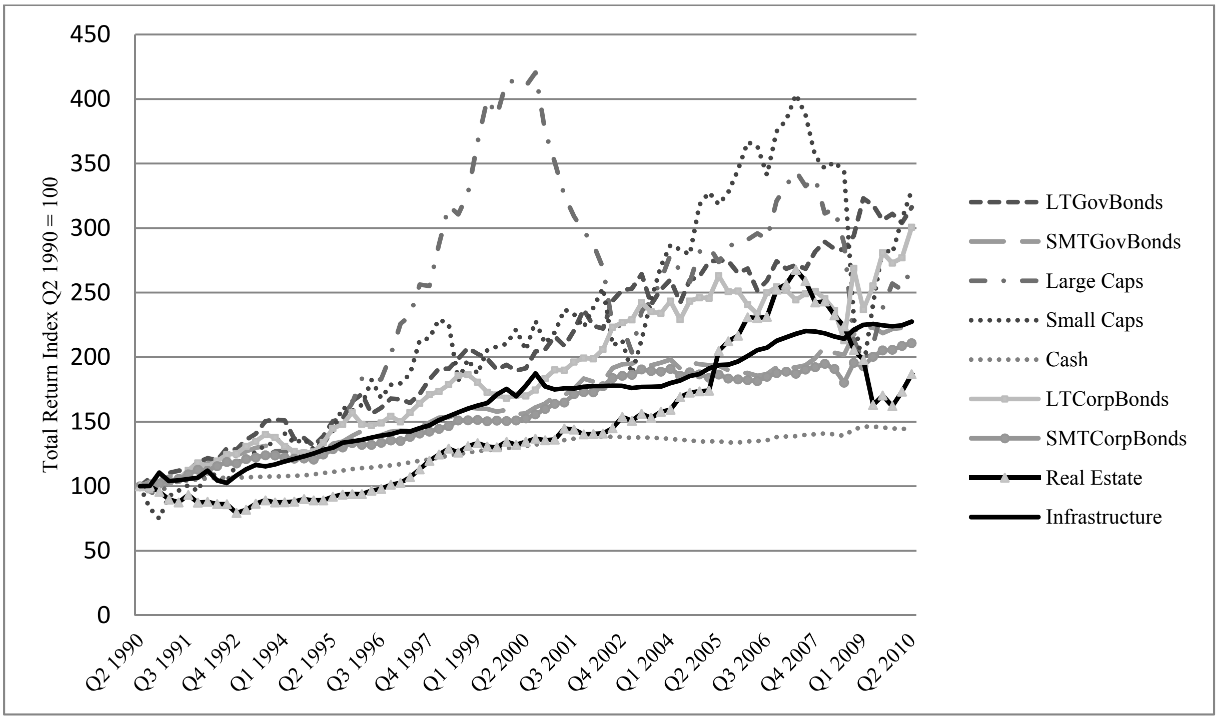
Table 1 shows the descriptive statistics from different asset classes when a holding period of four years[6] is assumed. In accordance with our base model, we use a target rate of 6% real return p. a. to calculate the LPM. Figure 2 shows total return indices of the different assets.

Table 1: Descriptive Statistics for Real Asset Returns (Holding Period: 4 Years) Q2 1994 – Q2 2010

	LTGovBonds	SMTGovBonds	Large Caps	Small Caps	Cash	LTCorpBonds	SMTCorpBonds	Real Estate	Infrastructure
Mean	23.87	15.32	38.11	33.99	7.80	21.59	14.63	26.55	20.11
	6.07	4.14	6.86	6.16	1.91	5.86	3.86	4.72	4.18
Median	24.85	17.20	29.93	35.51	7.97	20.87	16.19	27.19	22.04
	6.07	4.23	8.10	8.52	2.58	5.49	4.26	4.60	4.76
Sample Deviation	10.70	8.06	62.82	29.13	5.51	12.91	8.00	24.22	8.76
	7.89	4.61	18.72	17.59	1.84	8.65	3.94	11.25	3.70
Sample Variance	114.59	64.95	3946.98	848.80	30.40	166.74	63.99	586.53	76.79
	62.31	21.24	350.43	309.50	3.40	74.74	15.50	126.66	13.68
LPM (Target = 6%)	74.13	183.24	952.31	311.46	370.36	144.67	198.02	304.88	107.59
	31.99	20.44	189.84	139.33	20.10	38.19	17.39	92.47	14.71
Min	2.68	-3.32	-44.40	-41.66	-3.30	-12.60	-4.25	-25.24	-0.96
	-13.38	-5.11	-36.96	-44.77	-1.96	-14.60	-5.33	-29.89	-6.25
Max	57.62	28.60	176.90	105.04	15.49	47.64	26.71	71.44	37.32
	26.18	12.45	40.17	60.47	4.57	32.01	13.84	32.73	12.62

[6] The returns for different holding periods are constructed by employing overlapping returns on a quarterly basis. This means that a return for an investment period of z years could be calculated from Q1 of year t to Q1 of year t + z, another from Q2 of year t to Q2 of year t + z, and so on.

Figure 2: Total Return of Assets



Infrastructure assets do not yield very high returns, but are not exposed to high risk, irrespective of whether measured by variance or the LPM. This indicates that infrastructure might predominantly be allocated to low-risk low-return portfolios.

The correlation coefficients in Table 2 reveal a strong relationship between the returns on infrastructure and those on large cap stocks. Where does this high correlation come from? One argument could be that, in the long term, both assets exhibit the same underlying characteristics. Large cap stocks are mostly stocks of companies which exhibit high market power, pay stable dividends to their shareholders, but do not have high growth rates. Conservative infrastructure projects exhibit similar characteristics. They provide fundamental services to the economy, often have little growth potential and their main source of income is from the generated cash flow, rather than appreciation returns. In the short term, stock returns are highly volatile and driven by the equity market; their underlying large cap characteristics become apparent with medium- to long-term investment horizons. This could explain why both assets are correlated over longer investment horizons. The observation, that the correlation between infrastructure and large cap stocks rises when the holding period increases, supports this argument.

In order to further investigate the relationship between the returns on direct infrastructure and large cap stocks, we determine the extent to which the companies in the FTSE Large Cap Index do infrastructure business. We do so by filtering the companies in the FTSE Large Cap Index in terms of their sector code. According to the classification of infrastructure by the CEPRES index, we define a company as an infrastructure company if it operates telecommunication, utilities, waste, transportation or healthcare businesses. After filtering these companies out, we determine the share of infrastructure company market capitalization of the total market capitalization of the FTSE Large Cap Index at the end of the years 2004, 2006, 2008, 2010[7]. We find that the proportion of infrastructure companies' market capitalization to total market capitalization of the FTSE Large Cap Index is 18%, 23%, 26% and 25% in 2004, 2006, 2008 and 2010. Although we cannot calculate this number across the entire sample period, it indicates that a significant share of the performance of the total index stems directly from the performance of infrastructure companies. This further explains why returns from both index series are highly correlated over longer investment horizons.

Table 2: Correlations (Holding Period: 4 Years) Q2 1994 – Q2 2010

	LTGovBonds	SMTGovBonds	Large Caps	Small Caps	Cash	LTCorpBonds	SMTCorpBonds	Real Estate	Infrastructure
LTGovBonds	1.00	0.80	0.27	0.08	0.42	0.79	0.75	-0.20	0.10
SMTGovBonds		1.00	0.00	-0.32	0.59	0.65	0.92	-0.60	-0.14
Large Caps			1.00	0.43	0.58	0.06	0.06	0.38	0.80
Small Caps				1.00	-0.24	0.23	-0.15	0.50	0.34
Cash					1.00	0.13	0.60	-0.25	0.50
LTCorpBonds						1.00	0.76	-0.10	-0.22
SMTCorpBonds							1.00	-0.44	-0.14
Real Estate								1.00	0.22
Infrastructure									1.00

5.6 Results

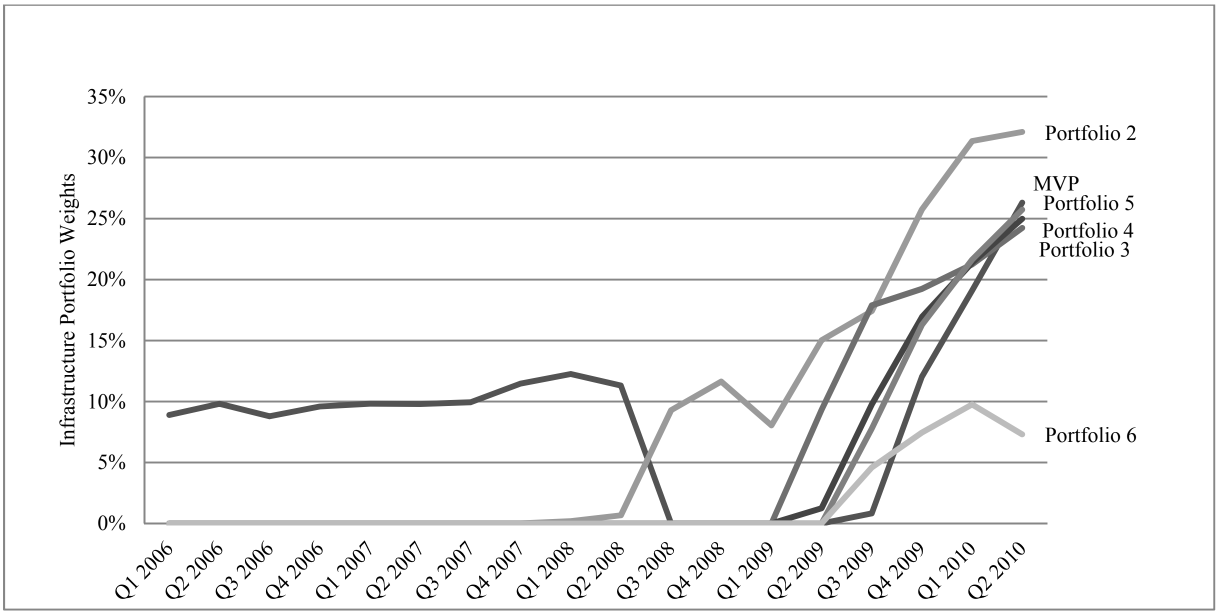
5.6.1 Mean-Variance Optimization

In the base MV-model, we find time-varying allocations with a maximum of more than 30% of total wealth allocated to infrastructure. Because infrastructure exhibits low expected returns and a low variance, it is allocated mostly to portfolios designed to have similar characteristics. Consequently, infrastructure plays an important role in the MVP with an average/maximum[8] proportion of 9%/26%. Furthermore, there is a significant proportion of infrastructure in port-

[7] Unfortunately, the index constituents of the FTSE Large Cap Index are only available from 2004 onwards. We thank FTSE for providing the index constituents.
[8] The average allocation in the base model is the average proportion of infrastructure from Q3 2006 to Q2 2010. The maximum allocation is the highest weight of infrastructure during this time period.

folios 2 to 6 (8%/32%, 5%/24%, 4%/25%, 4%/26% 2%/9%). The importance of infrastructure decreases with higher expected returns and it is not allocated from portfolio 7 onwards – an effect which is consistent over time.

Figure 3: Mean Variance Efficient Infrastructure Portfolio Weights Base Model



The proportion of wealth invested in infrastructure is not constant, but varies over time and in general, we find that the allocation to infrastructure increases over time. While, for example, the allocation to infrastructure in portfolio 2 is only 2% in Q2 2008, this proportion rises to more than 30% in Q1 2010. A similar pattern applies to portfolios 3, 4 and 5, but infrastructure does not enter these portfolios as early. The increasing allocation derives from stable returns, which remain relatively constant over time – even when the financial crisis begins to impact – while returns from most other assets declined significantly. Moreover, the correlations between infrastructure and short as well as long-term government bonds decrease over time, implying increasing diversification benefits. The high proportion of short-term government bonds in more recent portfolios therefore provides a rationale for expanding the allocation to infrastructure. As a result of the common downturn during the financial crisis, the correlations between most of the remaining assets increase over time. In general, this does not hold for infrastructure, making the asset class even more attractive from a diversification perspective[9]. Assets which are removed from the portfolio over time are short-term corporate

[9] Rolling correlations are not reported, but are available from the authors on request.

bonds and small cap stocks. Their real returns decrease significantly over time and their diversification benefits suffer as the analyzed time period increases.

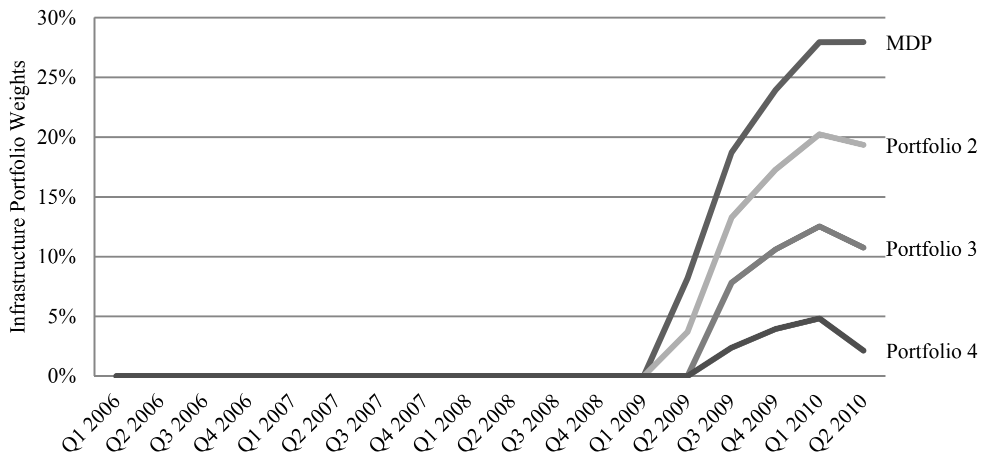
It should be noted that the presented allocations are extreme outcomes and constitute corner solutions. In reality, fund managers are restricted, either by institutional or regulatory issues, in allocating wealth to various assets. To reflect this situation, we impose restrictions on portfolio weights. We assume that a representative fund manager has to allocate at least 20%, but not more than 40%, to long-term government bonds and large cap stocks, respectively. Furthermore, the proportion of real estate is restricted to a minimum of 2% and a maximum of 10%. Small cap stocks are subject to a maximum of 10%. At least 5% of all funds must be allocated to cash, with a maximum allocation of 20%. As a result of the high correlation between infrastructure and large cap stocks, we find that the allocation to infrastructure is heavily dependent on the proportion of large caps in the portfolio. If a restriction is imposed on large cap stocks, infrastructure is removed from the portfolio. The high correlation between both assets and the high variance of large cap stocks creates a high covariance term, which is punished in the optimization. We test whether a change in the restriction of another asset evokes a similar effect. We cannot find any evidence of this, but demonstrate that removing infrastructure from the efficient portfolios is caused mainly by the inclusion of large cap stocks.

5.6.2 Mean-Downside Risk Optimization

In accordance with the results from the MV-optimization, we obtain time-varying allocations in which infrastructure is allocated predominantly to low-risk and low-expected-return portfolios mainly from Q1 2009 onwards. However, one main difference occurs when absolute infrastructure weights are compared; allocations to infrastructure are higher when risk is measured by variance, rather than by LPM. This holds across almost all portfolios and across time – only in some late MDPs, infrastructure is allocated to a greater extent than in MVPs. The portfolio with the lowest LPM contains an average/maximum proportion of infrastructure of more than 6%/28%, which then decreases in portfolios 2, 3 and 4 (4/20%, 2%/13%, 1%/5%). These results imply that infrastructure is a more attractive asset class for investors who are averse towards variance, rather than to downside risk[10][11]

[10] When “optimal” solutions from different optimization algorithms are compared, one has to consider that it does not make sense to draw a conclusion as to which optimization algorithm performs “better”. Each one, by definition, minimizes a different measure of risk and each approach is inferior from the perspective of the other. Therefore, a comparison is only appropriate when based on a common measure of risk. Hence, mean-variance optimization is appropriate for an investor who is averse towards deviations around the mean, while mean-downside risk optimization should be the favorable approach when an investor is averse towards failing to achieve a pre-defined target rate. Ultimately, which measure of risk is perceived as more appropriate by a given investor, is fundamental.

Figure 4: Mean Downside Risk Efficient Infrastructure Portfolio Weights Base Model



Where do these different allocations come from? It is evident that the risk structure of the analyzed assets changes with the applied risk measure. As Table 1 indicates, when risk is measured by the LPM, only long-term government bonds exhibit lower risk than infrastructure, but infrastructure is less risky than cash, short-term government bonds and short-term corporate bonds. The opposite holds when risk is measured by variance. These differences can be explained by the different definitions of risk. If risk is measured by variance, the implicit reference point for measuring risk is the mean. This number is lower for assets with low expected returns, so that the reference point is given by the return distribution of the respective asset. However, if risk is measured as falling short of a pre-specified target rate, assets that yield low returns could be assessed as very risky, if they do not meet these return requirements. This may be the case for short-term investments, as they should, on average, yield lower returns than long-term investments. In particular, this applies to short-term bonds and cash, and explains the significant reduction of those assets in low-expected-return portfolios. Therefore, compared to measuring risk by variance, infrastructure seems to be even more attractive from a DR-perspective, which contradicts our findings. However, the reduced allocation to infrastructure in MDR-efficient portfolios is caused mainly by the fact that long-term government bonds constitute a very attractive asset for DR-averse investors, as they offer

[11] In addition to the rolling window approach, we employ an extending window to construct efficient portfolios. We use 48 quarters for the initial optimization and extend this time-period successively by one quarter, until the optimization covers the full sample. The main conclusions remain unchanged in the sense that infrastructure is allocated to portfolios that exhibit low return and low risk. Furthermore, infrastructure weights are higher when the minimized risk measure is the variance. This confirms previous findings. The results are not reported, but are available upon request.

relatively high returns by being contemporaneously exposed to the lowest downside risk. Measuring risk by variance, however, reveals infrastructure as less risky than long-term government bonds. The rationale for including infrastructure in MDR-efficient portfolios stems from the relatively low downside correlation between infrastructure and long-term government bonds.

When asset weights are constrained, the allocation to infrastructure decreases significantly which is – similar to the MV-optimization – a result of the predetermined allocation to large cap stocks and its high downside correlation with infrastructure. Infrastructure is allocated to the two lowest DR-portfolios, but the allocation does not exceed a maximum of 7% over time.

To check for robustness, we consider different target returns between 3% and 8%. The general allocation pattern does not change with varying benchmark returns, but infrastructure remains still present in medium and especially in low-expected-return portfolios. With increasing targets, the proportion of infrastructure decreases and no more infrastructure is allocated when b = 8% p. a. Instead, small cap stocks and real estate find their way into the portfolio. This result comes along with the definition of risk and is rather intuitive: Infrastructure delivers stable low-to-medium returns. Therefore, it becomes riskier relative to other assets with higher target returns, making it less attractive for an inclusion in the portfolio. However, for targets of 3% and 4%, infrastructure is (almost) consistently allocated to the MDP across time, which underpins its attractiveness for conservative portfolios[12].

5.6.3 The Effects of Infrastructure on Portfolio Performance

To analyze the effect on portfolio performance when infrastructure enters, we firstly construct ten simple MV and MDR-portfolios over the entire sample period from Q2 1994[13] to Q2 2010, which include infrastructure. We then form ten portfolios with identical expected returns, but without infrastructure. Table 3 shows the increase in risk, compared to when infrastructure is included, and the allocation to infrastructure. As a result of its low (downside) risk and its diversification benefits, it comes as no surprise that removing infrastructure increases

[12] We also check for robustness by employing different lengths of rolling windows. When we employ a shorter rolling window (36) in the MV-optimization, we find higher allocations to infrastructure in the more recent period, than for a longer window (48). As infrastructure becomes more attractive over the course of the financial crisis, this information is weighted more heavily than for a longer estimation period. Although the use of a shorter window yields less precise estimations of expected returns and covariances, it enables estimating allocations over a longer period of time. By doing so, we find that infrastructure was already present in earlier periods (i.e. up to 11% in portfolio 1 and 5%-34% in portfolio 2 between Q1 2003 and Q2 2005) and is not only allocated as a result of the financial crisis. In general, these results also hold for MDR optimization. When the analysis is conducted with a longer rolling window (60), the average allocations to infrastructure vary to some extent in comparison to the base-model, but the asset is still present in the MVP, as well as in portfolios 2, 3 and 4 (avg./max: 12%/14%, 24%/27%, 25%/29%, 25%/31%) and in the MDR portfolio 1, 2 (25%/31%, 8%/11%), respectively. Therefore, the main conclusion, that the asset plays a vital role in portfolio diversification, especially in low-risk-low-return portfolios, remains unchanged.

[13] 16 quarters are required to construct the return on a four-year holding period.

portfolio risk. Removing infrastructure leads, for example, to an increase in portfolio risk by up to almost 24% in MV-portfolio 2, and by 31% in the MDP.

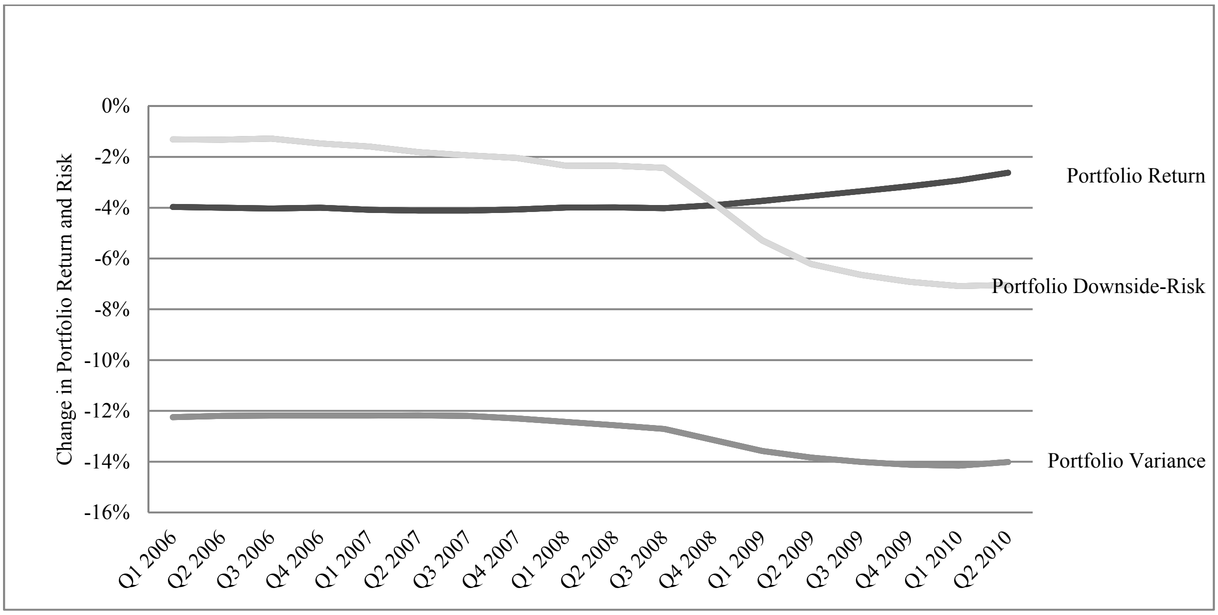
Table 3: Portfolio Risk and Return Characteristics with and without Infrastructure

Portfolio	1	2	3	4	5	6
Allocation to Infrastructure	0.12	0.25	0.29	0.31	0.06	0.00
Portfolio Return						
with Infrastructure	14.79	17.38	19.97	22.56	25.15	27.75
Portfolio Variance						
with Infrastructure	19.50	20.09	29.74	49.52	85.20	176.69
without Infrastructure	20.61	25.05	36.67	57.66	86.37	176.69
Increase in Portfolio Variance	5.68%	24.68%	23.33%	16.46%	1.38%	0.00%
Allocation to Infrastructure	0.31	0.14	0.01	0.00	0.00	0.00
Portfolio Return						
with Infrastructure	22.48	24.22	25.96	27.69	29.43	31.17
Portfolio LPM						
with Infrastructure	62.63	68.28	80.82	103.26	140.14	191.36
without Infrastructure	82.40	71.52	80.82	103.26	140.14	191.36
Increase in Portfolio LPM	31.57%	4.75%	0.01%	0.00%	0.00%	0.00%

This table shows portfolio risk for both risk measures when portfolios are constructed with and without infrastructure, and when the expected portfolio return is constant. Reported infrastructure allocations are estimated over the full sample period.

Figure 5 shows the time-varying risk-reducing characteristics of infrastructure for a typical institutional investor who invests 10% of total wealth to long and short-term government and corporate bonds. The allocation to large cap and small cap stocks is 25% and 20% respectively. The proportion of cash is 5% and real estate is weighted at 10%. We then reduce the allocation to each asset by 10% of its percentage allocation - except for cash – and allocate infrastructure instead, which results in a 9.5% proportion of infrastructure. When we compare the risk and return from these different portfolios over time, the impact of infrastructure is quite clear. The portfolio risk is reduced consistently over time (the decrease in variance ranges between 12.2% and 14.2%), while the reduction in return is only between 2.6% and 4.1%, measured on a relative basis. This indicates that the inclusion of infrastructure mainly contributes to reducing portfolio risk, while only marginally affecting the return. Similar results are obtained for the DR- approach.

Figure 5: Effect of Infrastructure on Portfolio Return and Risk Base Model



5.6.4 The Role of the Investment Horizon

As described in the data-section, infrastructure and real estate assets are subject to high transaction costs. The impact of transaction costs on returns becomes more accentuated with decreasing holding periods and risk, as well as return characteristics vary with the investment horizon. Therefore, the role of infrastructure might change along with the investment horizon. When a holding period of one year is assumed, buying and selling costs significantly reduce the return on infrastructure and the average expected return is negative. Nevertheless, the asset is still allocated to low-return portfolios – a result of its low variance and its diversification benefits. As the negative expected return is not accounted for when the MVP is formed, the highest proportion of infrastructure is allocated to the first portfolio and ranges between 11% and 38% over time. This is somewhat counter-intuitive and reveals one major shortcoming of the second central moment around the mean as a measure of risk. While a rational investor is unlikely to invest in an asset which has a negative expected return, but is likely to consider the asset as very risky, this is not accounted for by the variance. Variance only accounts for the average deviation around the mean, irrespective of whether the mean is positive or negative. Therefore, we do not consider the variance as an appropriate measure of risk when the investment horizon is relatively short, as the resulting allocations might yield a flawed picture of the role of infrastructure in the portfolio. An increase in the holding period induces a shift of infrastructure from low-expected return portfolios to those portfolios which aim at yielding a higher expected return. For example, when the investment horizon is extended to 6 (7) years, infrastructure is allocated even to portfolio 9 with maximum weights of more than 19% (24%) and is, furthermore, almost consistently present in medium-expected-return portfolios over time. In addition to a decrease in transaction costs, there is one major reason why infrastructure becomes more important for portfolios that are constructed to yield higher expected returns. Mature infrastructure investments, as mirrored by the index at hand, do not generally yield very high returns, but exhibit a low probability of yielding losses. This return behavior is advantageous in the long run when compounded returns are employed to measure the expected return on an investment. Consequently, in comparison to returns on other assets, the return on infrastructure increases disproportionately when the holding period increases. This is illustrated in Table 4.

Table 4: Asset Returns Dependent on Holding Period

Holding Period in Years	LTGovBonds	SMTGovBonds	Large Caps	Small Caps	Cash	LTCorpBonds	SMTCorpBonds	Real Estate	Infrastructure
2	12.18	8.24	14.32	14.66	3.83	10.80	7.38	5.33	2.92
3	18.28	11.95	25.36	24.35	5.76	16.04	10.96	15.38	11.29
4	23.87	15.32	38.11	33.99	7.80	21.59	14.63	26.55	20.11
5	31.25	19.45	51.67	45.51	9.87	28.39	18.79	38.47	29.26
6	38.75	23.92	63.03	55.29	12.04	35.36	23.26	50.52	38.75
7	46.97	29.12	73.57	66.15	14.45	43.22	28.48	62.93	48.69

This table shows the compounded returns on the different assets for different holding periods.

When the LPM is the relevant measure of risk, the results differ to a certain degree. Because transaction costs significantly reduce the return on infrastructure for short holding periods, it makes the asset very risky from a DR-perspective. This makes sense, as the reference point for measuring risk is the target return, instead of the mean, so that negative returns are punished more severely than by the variance. As a result, no infrastructure is allocated to any portfolio for a holding period of one year, and only marginal allocations appear for a two-year investment horizon. This result seems to be more intuitive from a rational investor's point of view.

However, infrastructure becomes more attractive for low-return portfolios, the longer the holding period. While the proportion of infrastructure in MDR-portfolios is below that of MV-portfolios in the base-model, this reverses with increasing investment horizons, but infrastructure becomes an important asset to protect an investor from downside risk. If the investment horizon is set to 6 (7) years, average/maximum allocations in portfolio 1, 2 and 3 are 13%/40% (21%/38%), 11%/36% (16%/33%) and 9%/31% (13%/29%), respectively. The increasing importance of infrastructure is based on the fact, that, due to stable long-term returns, the downside risk decreases with increasing investment horizons. This is illustrated in Table 5. For an investment horizon of 6 and 7 years, infrastructure has the lowest downside risk of all considered assets. Because the downside risk of long-term government bonds increases over longer time horizons, they are replaced by infrastructure. These results show that if investment horizons are sufficiently long, infrastructure becomes very attractive in terms of DR-protection and accounts for a substantial part of overall wealth – especially in low-expected-return portfolios.

Table 5: Lower Partial Moments

Holding Period in Years	LTGovBonds	SMTGovBonds	Large Caps	Small Caps	Cash	LTCorpBonds	SMTCorpBonds	Real Estate	Infrastructure
1	31.99	20.44	189.84	139.33	20.10	38.19	17.39	172.32	126.66
2	34.97	56.21	461.15	229.99	82.24	63.97	54.32	293.75	125.33
3	53.72	110.52	698.46	296.91	196.81	104.64	113.60	331.24	120.61
4	74.13	183.24	952.31	311.46	370.36	144.67	198.02	304.88	116.03
5	99.15	276.88	1228.57	355.79	616.11	171.43	306.29	227.57	113.86
6	122.11	398.33	1430.03	211.78	943.18	202.36	440.94	177.30	111.23
7	158.69	552.14	1812.26	270.12	1354.12	223.80	588.97	130.27	111.62

This table shows the LPMs for different holding periods and for different assets. The underlying target return is 6%p.a. and it is compounded according to the holding period.

In accordance with the results from the MV-optimization, the allocation to infrastructure increases with longer investment horizons in portfolios that have medium and high-expected-returns. However, compared to MV-efficient portfolios, the allocation to infrastructure is not as high, but real estate is allocated instead. This results from real estate's low downside risk, compared to variance, for longer investment horizons. Figure 6 and 7 show infrastructure allocations for an investment horizon of 6 years.

Figure 6: Mean Variance Efficient Infrastructure Portfolio Weights Holding Period 6 Years

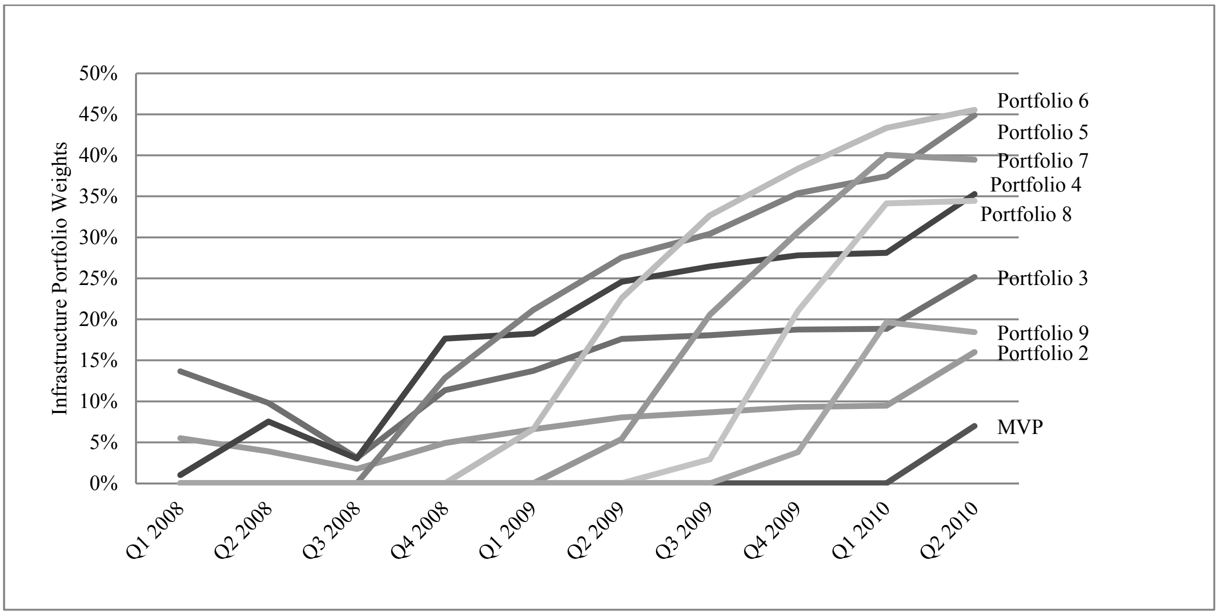
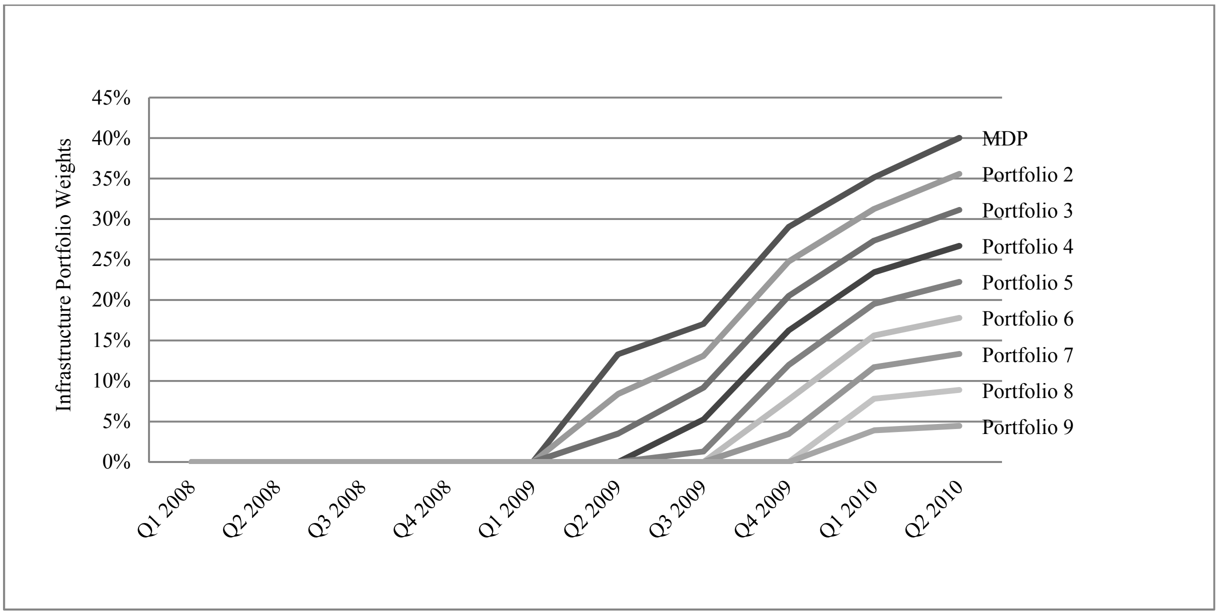


Figure 7: Mean Downside Risk Efficient Infrastructure Portfolio Weights Holding Period 6 Years



5.6.5 Nominal vs. Real Returns

Infrastructure is often supposed to provide a hedge against inflation. Therefore, the results may differ, depending on whether real or nominal returns are employed, and infrastructure might be more attractive in a real framework. However, we find no major differences in the allocations of our base model, and not even for longer holding periods. This result is somewhat unexpected, but might stem from the fact that the indexation of infrastructure cash flows is dependent on the specific project. Due to the fact that we employ a diversified index, not all projects are hedged against inflation. Roedel and Rothballer (2011), for example, show that only infrastructure firms with high pricing power can improve inflation hedging. Moreover, one further possibility might be to distinguish between expected and unexpected inflation. Although we cannot find any evidence that infrastructure assets are more attractive in a real framework, this topic might be suitable for future research.

3.6.6 Infrastructure and Real Estate

Many institutional investors do not have a separate target allocation for infrastructure investments, but these are rather part of their alternative assets or real estate allocation. Although there are theoretical differences between real estate and infrastructure, both assets exhibit some common characteristics and are often mentioned “in one breath”[14]. For that reason, we test whether the inclusion of infrastructure in particular affects the allocation to real estate. We do so by forming time-varying portfolios in which infrastructure weights are set to zero. Then, we compare these allocations to the portfolio weights from our base model. The descriptive statistics of infrastructure and real estate returns do not indicate a high degree of similarity, as real estate exhibits higher risk and a higher expected return than infrastructure and both assets are not very highly correlated. This also holds over time. Therefore, it is no surprise that the availability of infrastructure for portfolio selection does, on average, not affect the weightings to real estate very extensively. Nevertheless, real estate is partially removed from the latest MV-portfolios when infrastructure is included. As illustrated in Figure 8, the removed share ranges from 0% to a maximum of 9%. Although the proportion of real estate decreases, it is still a viable asset with allocations between 5% and more than 40%. This underpins recent results, as in Finkenzeller et al. (2010), who find that infrastructure and real estate constitute two distinct asset classes. However, when infrastructure enters the portfolio, we observe a switch in portfolio weights from cash (and to a much lesser extent, from real estate) to short-term government bonds and to infrastructure in low-return portfolios. This is caused by the low correlation between infrastructure and short-term government bonds, making infrastructure attractive from a diversification perspective. For low-to-medium-return portfolios, the inclusion of infrastructure decreases the allocation to short-term government bonds (and to a lesser extent, the allocation to real estate), but increases the proportion of long-term government bonds. This result derives from the low correlation of infrastructure

[14] For example illiquidity, large lot sizes, stable cash-flows and potential inflation hedging characteristics are supposed to be common to infrastructure and real estate. However, infrastructure assets are often inherently monopolistic and provide essential services. Moreover, the infrastructure market is often characterized by the decision making competency of public authorities in terms of regulation. Beyond that, the infrastructure market is, due to a shortage of research and high quality data, even less transparent than the real estate market.

with long-term government bonds – which constitute an important asset in the portfolios. Though short-term government bond returns are not related to that of infrastructure, their allocation decreases, as infrastructure offers a higher return, while exhibiting almost as low variance.

Long-term government bonds and real estate are the assets which are mainly removed when infrastructure enters MDR-efficient portfolios. The proportion of government bonds diminishes, so as to exploit the diversification effects with infrastructure, while the allocation to real estate diminishes in low-risk portfolios, as infrastructure offers a lower level of downside risk. This is shown in Figure 9. Nevertheless, real estate remains an important asset for portfolio diversification over time.

Therefore, for both optimization algorithms, we find that the inclusion of infrastructure affects the allocation to real estate, but we can find no evidence that infrastructure is able to replace real estate.

Figure 8: Effect of Infrastructure on Real Estate Portfolio Weights Mean Variance - Base Model

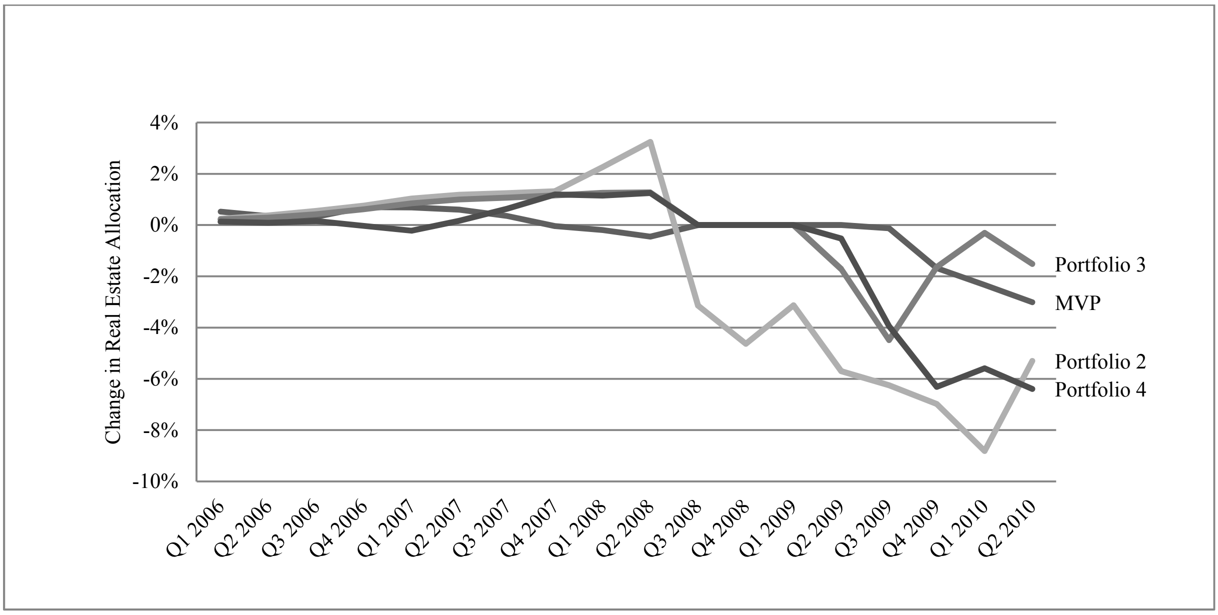
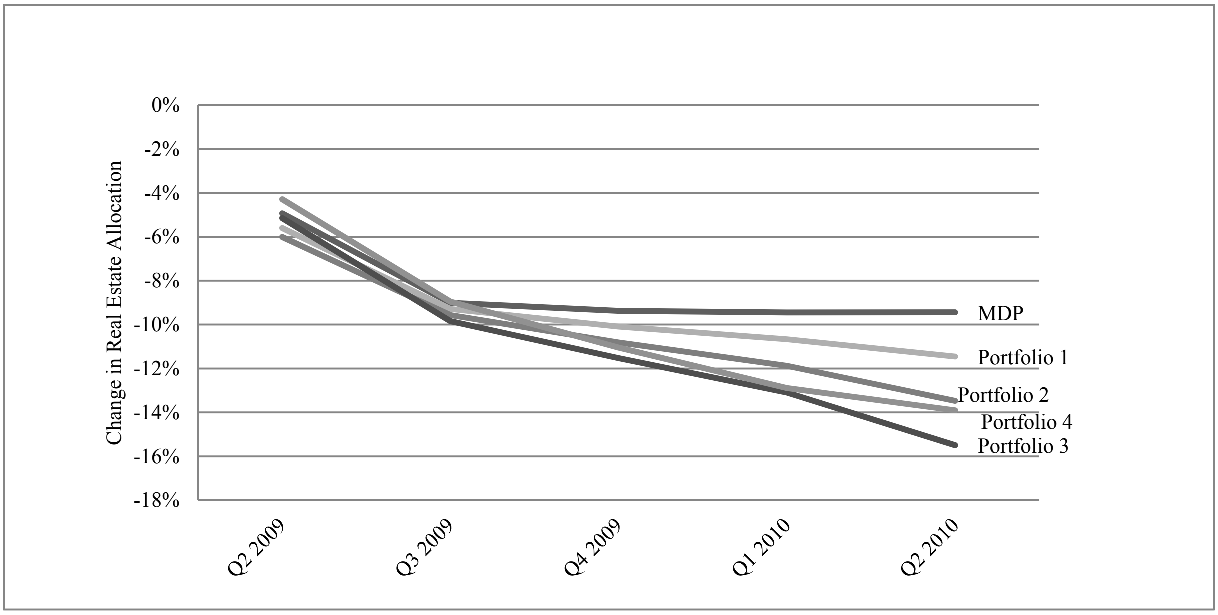


Figure 9: Effect of Infrastructure on Real Estate Portfolio Weights Mean Variance - Base Model



5.7 Conclusion

Infrastructure has emerged as a separate asset class, but research on its role in mixed asset portfolios is scarce. This study contributes to filling this research gap and sheds light on the issue of whether and to what extent direct infrastructure should be allocated to a multi-asset portfolio. To do so, we construct time-varying multi-asset portfolios using two different optimization algorithms – a standard mean-variance approach as well as a mean-downside risk methodology. Our results show that infrastructure is an important asset for portfolio diversification and is, in particular, allocated to low and medium-risk portfolios with maximum allocations of 32% and 28%, respectively. With increasing investment horizons, infrastructure is also allocated to portfolios which aim at yielding higher expected returns – a result which stems from stable returns and a low probability of yielding losses. Moreover, infrastructure proves to be a particularly attractive investment for long-term downside risk-averse investors who aim at earning low returns.

Infrastructure and real estate have similar underlying characteristics and are often perceived as related assets. However, we cannot find strong evidence that the inclusion of infrastructure significantly affects the weightings to real estate, as it is not able to replace property in the portfolio. Different risk and return characteristics, along with diverging asset allocation patterns, speak in favor of two separate asset classes.

Infrastructure exhibits a high positive correlation with large cap stocks, which makes an investment less attractive when a certain proportion of total wealth has already been allocated to large cap stocks. This result is obtained, independent of the optimization algorithm. If investors were aware of this fact, it could explain why there is a lower allocation to infrastructure in institutional investment portfolios than suggested by theoretical models.

There is no simple answer to the question of how much infrastructure is "optimal" for a multi-asset portfolio, as this depends on various parameters, such as the holding period of the assets, the investor's expected return, perception of risk, target return, as well as the market phase. However, we obtain stable and conclusive evidence that the inclusion of infrastructure is beneficial, especially in low to medium-return portfolios and for investors who exhibit longer investment horizons. We do not know exactly how much infrastructure is on average allocated to investment portfolios, as no reliable data are available. However, there is some indication that it is less than suggested by our empirical model. Our results do not necessarily suggest that it is beneficial for all investors to reallocate their portfolios and to increase their allocation to infrastructure, but we provide some evidence that the inclusion of infrastructure might deliver a better risk-return tradeoff than conventional portfolio allocations, which comprise mainly stocks, bonds and real estate. This insight might be especially useful for investors whose aim is not to earn superior returns, but to protect their portfolios from extreme shortfalls and/or who have longer investment horizons.

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6. Direct Infrastructure Investment and its Role in Drawdown-Efficient Portfolios

Tobias Dechant Konrad Finkenzeller

Abstract

This paper investigates the role of direct infrastructure in a multi-asset portfolio, by employing a US transaction-based index which covers the period Q2 1990 to Q2 2010. We use an algorithm which minimizes Conditional Drawdown at Risk (CDaR) to determine time-varying asset allocations. In addition to infrastructure, the asset menu comprises large and small cap stocks, bonds of different maturities and cash. Our results show that infrastructure plays an important role and is allocated predominantly to portfolios that exhibit low-to-medium risk exposure. We cannot find any evidence that infrastructure provides a hedge against pension liabilities, but it is a viable asset when various predefined target returns are the reference point for evaluating portfolio risk and performance. We also find that infrastructure is a hedge against systematic equity-market downside risk and contributes to a portfolio which is designed to protect an investor against a decline in portfolio value when the equity market drops.

6.1 Introduction

During the last few years, direct infrastructure investments have moved into the focus of many institutional investors[1]. This private involvement is driven by financial strains on governments, which render the public sector unable to guarantee adequate infrastructure provision[2]. The imbalance between infrastructure provision and demand is expected to gain further momentum and increase privatization pressure over the long run. According to the OECD (2006, 2007), cumulative global infrastructure needs are estimated to rise to US$ 71 trillion by 2030, this is about four times the value of the current global infrastructure stock and includes the enormous requirements of developing countries.

Despite the heterogeneity of the infrastructure universe, investors are attracted by several major characteristics associated with the asset class. Firstly, due to their monopolistic nature, infrastructure investments are expected to provide stable and predictable cash flows which may enable investors to match their long-term liabilities. As a result of this monopolistic character and the provision of basic services, cash flows from infrastructure investments are also assumed to be less vulnerable to economic downturns than other more cyclical assets. This could make them attractive to investors seeking new sources of diversification, in order to hedge their portfolios against downturns of traditional assets such as stocks and bonds. Studies from Newell and Peng (2008) as well as Dechant, Finkenzeller and Schaefers (2010) provide some empirical evidence of the benefits of including infrastructure in an investment portfolio. Thirdly, some specific infrastructure investments, such as alternative energies, are associated with the increasing significance of socially responsible investment strategies and the need for an enhanced public image.

The increasing attraction of infrastructure investments, along with its unique asset characteristics, have confirmed the role of infrastructure as separate asset class and large institutional investors have begun to establish specific allocation targets. Although the average allocation to infrastructure is not expected to exceed 2% on average globally (Croce, 2011; Inderst, 2010), large North American and Australian pension schemes already hold up to 15% of their total wealth in infrastructure .

However, the market for direct infrastructure assets is still young and opaque, and specific barriers have to be considered. Political structures and regulations with respect to privatizing

[1] Infrastructure assets can be divided into two main categories of economic and social infrastructure. Economic infrastructure includes long-lasting, large-scale physical structures like transportation and communication infrastructure, as well as energy and utility facilities. Social infrastructure, on the other hand, includes education, healthcare, waste disposal, as well as judicial facilities (see, for example, Kaserer, Buchner, Schmidt and Krohmer, 2009). According to Mansour and Patel (2008), the entire global infrastructure universe is estimated to be worth $20.5 trillion.

[2] The relationship between infrastructure provision and economic growth is well established in the macroeconomic literature (Röller and Waverman 2011, WEF 2010).

are significantly different, immature or absent across the globe. Large investment lot sizes[3], along with an immature secondary market make direct infrastructure an illiquid asset. Furthermore, the specific design and unique characteristics requires specialized knowledge and dedicated resources, so as to provide adequate due diligence and a sufficient risk monitoring process. To generate scale effects in managing infrastructure assets, a sufficient allocation should be made. Although a range of different listed performance benchmarks does exist, the market remains subject to a shortage of data on direct infrastructure performance, and lacks sufficient academic research to understand the general behavior of the asset (Croce, 2011; Inderst, 2010).

The research stream which deals with direct infrastructure asset allocation basically covers two markets, Australia, the pioneer of privatization and private infrastructure investment, and the United States. Finkenzeller, Dechant and Schäfers (2010) use a sample of major unlisted Australian infrastructure funds to depict direct infrastructure performance over the Q4 1990 to Q1 2009 horizon. The authors construct efficient portfolios for downside risk-averse investors and provide evidence of the diversification benefits of direct infrastructure. The constructed portfolios contain a significant proportion of direct infrastructure, when the expected return is not particularly high. Newell, Peng and DeFrancesco (2011) employ a similar data set over the period Q3 1995 to Q2 2009. Their analysis is based on variance, return and correlation characteristics. They show that direct infrastructure has attractive risk adjusted returns and offers significant diversification benefits against equities and bonds. These results also apply when the impact of the financial crisis is accounted for. Based on a set of different US asset returns and a transaction-based direct infrastructure series, Dechant et al. (2010) analyze the role of direct infrastructure in a conditional shortfall risk framework. They find that infrastructure exhibits unique asset characteristics and they underpin the significance of direct infrastructure for portfolio diversification. Efficient portfolios contain a significant proportion of infrastructure which, however, depends on the expected return and state of the equity market. Moreover, the authors highlight the importance of infrastructure for portfolio diversification in bear markets.

This paper contributes to the existing literature by investigating the role of direct infrastructure in a multi-asset portfolio over time, considering different investment scenarios. To construct efficient portfolios, we use a horizon-dynamic algorithm which minimizes Conditional Drawdown at Risk (CDaR), for a given level of expected return. Chekhlov, Uryasev and Zabarankin (2000, 2003, 2005) define a portfolio's drawdown on a sample path as the drop in

[3] According to Prequin (2011), an average infrastructure deal size is estimated to be at around US$ 400 million.

the uncompounded portfolio value, compared to the maximum value attained in the previous moments on that sample path. This approach is appropriate for investors who define their allowed losses as a percentage of initial wealth. The CDaR approach is based on stochastic programming and has proven its efficiency in various portfolio management applications, including Rockafellar and Uryasev (2002), Krokhmal, Uryasev and Zrazhevsky (2002), Cheklov et al. (2005) as well as Berkelaar and Kouwenberg (2010). In particular, we firstly construct unconstrained and constrained investment portfolios. Secondly, we introduce the assumption that an investor is averse to falling short of the return on pension liabilities or some predefined target return. Thirdly, we investigate the role of infrastructure when the investor's main aim is to hedge against downside systematic equity market risk.

The article is organized as follows. The next section introduces the data and presents some descriptive statistics. We continue with a description of the methodology. The results of different models are given in Section 4 and the final section concludes.

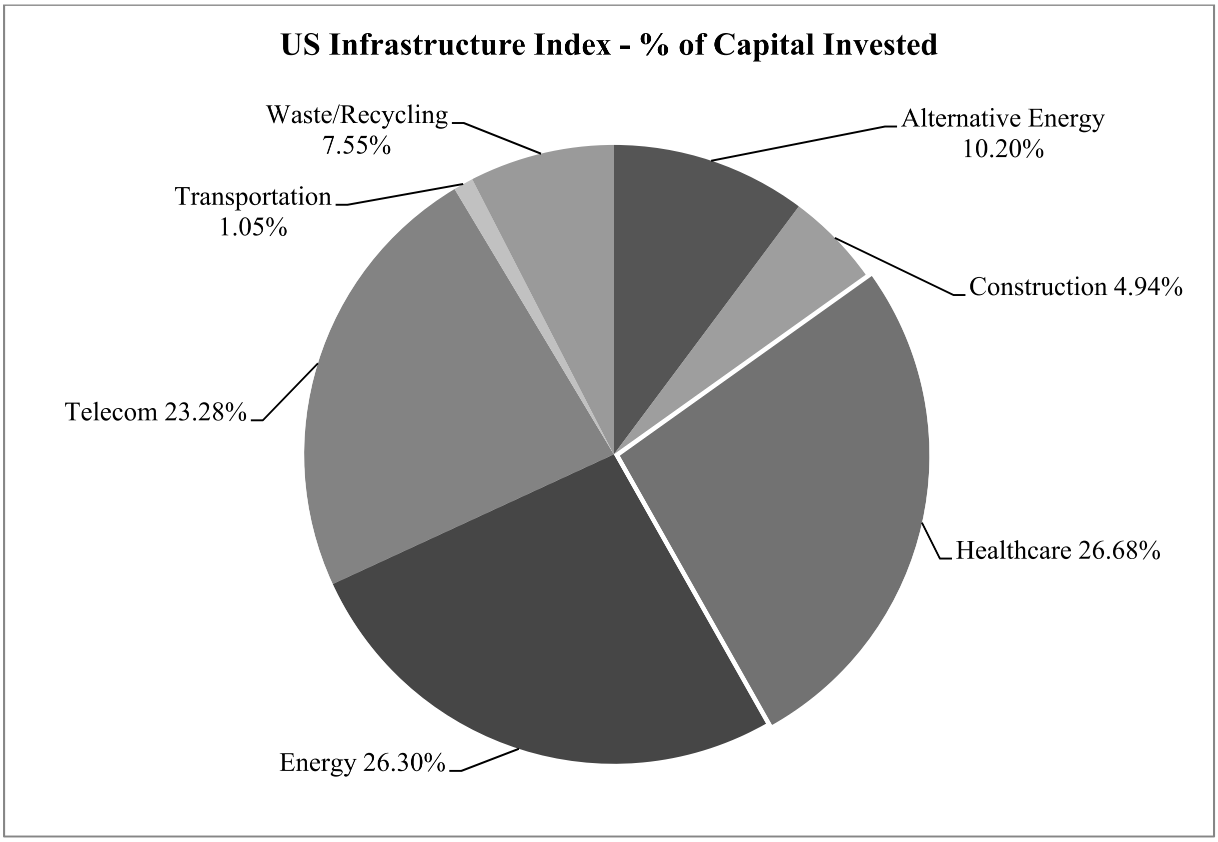
6.2 Data and Descriptive Statistics

We employ US total return data from ten different asset classes, which are deflated by the consumer price index. Observations have a monthly frequency and cover the period from Q2 1990 to Q2 2010. The asset selection focuses on a menu of investment opportunities which are typically preferred by institutional investors. In particular, we consider direct infrastructure, large cap stocks, small cap stocks, cash, short, medium, and long-term government and corporate bonds.

The direct infrastructure performance index is based on transactions and is provided by the Center of Private Equity Research (CEPRES). It is a sub-index of a more general CEPRES dataset of private equity investments, which is employed in studies such as Krohmer, Lauterbach and Calanog (2009), Franzoni, Nowak and Phalippou (2011) and Füss and Schweizer (2011). The specific infrastructure data is applied in studies such as Kaserer, Buchner and Schmidt (2009), Dechant et al. (2010), Bitsch, Buchner and Kaserer (2011), as well as Finkenzeller and Fleischmann (2011). The infrastructure index covers a sample of 930 individual operating infrastructure projects in the US and is based on a broad reporting sample of 135 global infrastructure equity investors. The index construction methodology corresponds with Peng (2001) and is based on the Method of Moment Repeat Sales Regression (MM-RSR). A more formal and detailed illustration of the applied procedure and the data implementation process is provided by Schmidt and Ott (2006).

To reflect unbiased direct infrastructure performance, the index is free of survivorship bias, and corrected for gearing, carried interest, management fees and transaction costs, which reflect the illiquidity of the underlying asset. The capitalization of the index adds up to around \$27.2 billion of invested equity and only includes sectors which are in accordance with the definition of infrastructure from Kaserer et al. (2009). Figure 1 shows the average sector weights, which are calculated according to capital invested over the entire sample period. The average index shares are 34% for social infrastructure (health care, waste/recycling) and 66% for economic infrastructure (transportation, telecom, (alternative) energy, construction). The relatively high weights for health care, energy and telecom assets are in line with the investment objectives of various types of investors (Probitas, 2011) and reflect direct investment opportunities in the market. Together with a sufficient number of transactions and a high market capitalization, the index constitutes an appropriate tool for benchmarking direct infrastructure performance in the US.

Figure 1: Infrastructure Index Sector Weights



The remaining assets are collected from Thomson Reuters DataStream. The general stock market is represented by the S&P 500 Composite series, whereas the S&P 600 small cap series represents the performance of small cap stocks. The Cash index is the JP Morgan JP US Cash 1 month series. To mirror corporate as well as government bond performance, we use the Citigroup US Broad Investment-Grade (USBIG) index series. We choose a duration of 1-5 years for short-term bond performance (US Citigroup USBIG Government 1-5Y and US Citigroup USBIG Corporate AAA/AA 1-5Y), a duration of 3-7 years for medium-term bond performance (US Citigroup USBIG Government 3-7Y and US Citigroup USBIG Corporate AAA/AA 3-7Y) and a duration of 10 or more years (US Citigroup USBIG Government 10+Y and US Citigroup USBIG Corporate AAA/AA 10+Y) to represent long-term bond performance.

Table 1: Descriptive Statistics for Monthly Asset Returns May 1990 – July 2010

	STGovBonds	MTGovBonds	LTGovBonds	STCorpBonds	MTCorpBonds	LTCorpBonds	Cash	Small Caps	Large Caps	Infrastructure
Mean	0.29%	0.37%	0.51%	0.32%	0.36%	0.47%	0.13%	0.46%	0.38%	0.27%
Max	3.05%	5.01%	10.75%	3.46%	4.65%	14.18%	2.34%	17.24%	14.47%	4.21%
Min	-1.95%	-3.97%	-12.13%	-3.96%	-5.26%	-10.38%	-1.06%	-23.52%	-15.86%	-4.69%
St. Deviation	0.72%	1.10%	2.74%	0.84%	1.21%	2.55%	0.31%	5.68%	4.53%	1.20%
Skewness	0.05	-0.09	-0.35	-0.43	-0.39	0.22	1.28	-0.78	-0.61	-0.79
Kurtosis	3.96	4.87	5.61	6.07	5.64	9.34	13.94	5.32	4.62	9.94

Table 1 presents the descriptive statistics for various asset classes. The infrastructure index does not yield high returns, but is, on the other hand, also not exposed to high levels of standard deviation. Contrary to intuition, small and large cap stocks are not the assets with the highest level of expected return. The returns from both assets are influenced by almost a decade of extreme impacts on the stock market, thus resulting in the presented numbers. Long-term government bonds yield the highest average return over the sample period. This is likely to have been driven by a favorable interest policy in recent years and a capital flow away from the equity into the government bond market.

Table 2: Correlations of Monthly Asset Returns May 1990 – July 2010

	STGovBonds	MTGovBonds	LTGovBonds	STCorpBonds	MTCorpBonds	LTCorpBonds	Cash	Small Caps	Large Caps	Infrastructure
STGovBonds	1.00	0.97	0.77	0.84	0.83	0.66	0.48	-0.15	-0.03	0.06
MTGovBonds		1.00	0.86	0.84	0.87	0.75	0.34	-0.12	-0.01	0.04
LTGovBonds			1.00	0.69	0.78	0.87	0.13	0.03	0.08	0.04
STCorpBonds				1.00	0.98	0.79	0.28	-0.02	0.08	0.02
MTCorpBonds					1.00	0.86	0.18	0.02	0.12	0.01
LTCorpBonds						1.00	0.07	0.15	0.21	0.01
Cash							1.00	-0.18	-0.07	0.22
Small Caps								1.00	0.79	-0.02
Large Caps									1.00	-0.05
Infrastructure										1.00

Correlations between the returns on various assets are presented in Table 2. It shows that direct infrastructure is not significantly related to any other asset return, but only to cash. Moreover, infrastructure does not exhibit any significant diversification benefits, which means that it is not negatively and significantly correlated to any asset. The significant correlation between infrastructure and cash is essentially intuitive, as both assets provide stable returns. The fact that infrastructure returns are not correlated with other asset returns conforms to the characteristics of infrastructure. Conservative projects, reflected by the return series at hand, provide fundamental and basic services to the economy, and are largely independent of macroeconomic cycles – in contrast to equities or corporate bonds, for example. This asset profile supports the argumentation of previous studies, such as Newell and Peng (2008) and Dechant et al. (2010), who provide evidence that infrastructure constitutes a separate asset class with a unique risk/return profile.

6.3 Methodology

We consider conditional drawdown at risk (CDaR) as a risk measure for portfolio optimization. CDaR is closely related to the concept of conditional value at risk (CVaR) which is defined by Rockafellar and Uryasev (2000, 2002) for general loss distributions. CDaR is dependent on the sample path of the uncompounded value of a portfolio. Chekhlov et al. (2003, 2005) define a portfolio's drawdown on a sample path, as the decline in the uncompounded portfolio value, compared to the maximum value attained in the previous moments on that sample path. The drawdown calculates losses for the most "unfavorable" moment in the past, compared to the current moment. It quantifies, in an aggregated manner, the frequency, as well as the magnitude of portfolio drawdowns over a given time period. This approach is appropriate for investors who define their allowed losses as a percentage of initial wealth. The theoretical concept of drawdown risk is given as follows.

Suppose that the initial portfolio value is equal to 1. The uncompounded portfolio value at time j then equals

$$v_j(x) = \sum_{i=1}^{n} (1 + \sum_{s=1}^{j} r_{is}) x_i \tag{1}$$

where r_{ij} is the return on asset i in time period j, with $j = 1,..., J$. Asset weights in the portfolio are denoted by x_i, $i = 1,..., n$.

The drawdown function $\psi(x, j)$ for a portfolio at time j is defined as the decline in portfolio value, compared to the highest portfolio value achieved before that time moment j.

$$\psi(x, j) = \max_{1 \le k \le j} \left\{ \sum_{i=1}^{n} \left(\sum_{s=1}^{k} r_{is} \right) x_i \right\} - \sum_{i=1}^{n} \left(\sum_{s=1}^{j} r_{is} \right) x_i \tag{2}$$

This means that, for a specified sample path, the drawdown function is defined at each point in time. In order to aggregate all drawdown information over a certain time period, and to evaluate portfolio performance across the entire sample path, one can, for example, choose the Maximum Drawdown (MaxDD)

$$MaxDD = \max_{1 \le t \le J} \left\{ \max_{1 \le k \le j} \left\{ \sum_{i=1}^{n} \left(\sum_{s=1}^{k} r_{is} \right) x_i \right\} - \sum_{i=1}^{n} \left(\sum_{s=1}^{j} r_{is} \right) x_i \right\} \tag{3}$$

or the Average Drawdown (AvDD)

$$AvDD = \frac{1}{J} \int_{0}^{J} \psi(x, j)\, dj \tag{4}$$

as a measure of portfolio risk.

A disadvantage of the Maximum Drawdown is that it focuses only on one single event, the worst case in the sample path. This outcome might be very specific, and risk management based only on this event may be too restrictive. A further extreme is the average drawdown, which accounts for all drawdowns in the sample path. The shortcoming of this measure is that it treats even relatively small deviations as risky outcomes and is prone to averaging out large drawdowns. The Conditional Drawdown at Risk, as demonstrated by Chekhlov et al. (2003, 2005), combines both the drawdown approach and the concept of conditional value at risk. For a given value of the tolerance parameter α, the α-CDaR is defined as the mean of the highest (1-α)*100% of all drawdowns over an analyzed period of time.

If the product $(1-\alpha)J$ is an integer, the CDaR function $\Delta_\alpha(x)$ is defined as

$$\Delta_\alpha(x) = \eta_\alpha + \frac{1}{(1-\alpha)J}\sum_{j=1}^{J}\max\left\{0, \max_{1\le k\le j}\left[\sum_{i=1}^{n}\left(\sum_{s=1}^{k} r_{is}\right)x_i\right] - \sum_{i=1}^{n}\left(\sum_{s=1}^{j} r_{is}\right)x_i - \eta_\alpha\right\} \tag{5}$$

$\eta_\alpha = \eta_\alpha(x)$ represents the threshold which is exceeded by $(1-\alpha)J$ drawdowns. Therefore, $\Delta_\alpha(x)$ is the average of the $(1-\alpha)J$ highest drawdowns in the analyzed sample path.

If $(1-\alpha)J$ is not an integer, the CDaR $\Delta_\alpha(x)$ is the solution of

$$\Delta_\alpha(x) = \min_{\eta}\left\{\eta + \frac{1}{(1-\alpha)J} * \sum_{j=1}^{J}\max\left\{0, \max_{1\le k\le j}\left[\sum_{i=1}^{n}\left(\sum_{s=1}^{k} r_{is}\right)x_i\right] - \sum_{i=1}^{n}\left(\sum_{s=1}^{j} r_{is}\right)x_i - \eta\right\}\right\} \tag{6}$$

Table 3 shows conditional drawdowns of different assets calculated over the full sample period and for various levels of α.

Table 3: Conditional Drawdowns of Asset Returns Full Sample

alpha	STGovBonds	MTGovBonds	LTGovBonds	STCorpBonds	MTCorpBonds	LTCorpBonds	Cash	Small Caps	Large Caps	Infrastructure
0.00	1.00%	1.43%	4.44%	1.03%	1.59%	3.75%	0.66%	10.57%	24.25%	0.97%
0.80	3.39%	4.31%	11.34%	3.39%	4.76%	10.88%	2.69%	33.90%	62.75%	3.12%
0.90	4.19%	5.12%	12.69%	4.29%	5.57%	12.65%	3.37%	44.06%	71.56%	3.70%
0.95	4.93%	5.67%	13.87%	4.99%	6.41%	14.11%	3.67%	54.76%	77.96%	4.23%
0.99	5.41%	6.64%	15.61%	6.11%	8.65%	19.86%	4.50%	74.61%	89.56%	5.30%

It can easily be seen that, independent of the confidence parameter, infrastructure is likely to be an attractive asset when an investor's main aim is to protect her portfolio from drawdown risk; only cash is exposed to less drawdown risk, but contemporaneously offers a significantly lower average return. This conforms to the perception of infrastructure as a low-risk, low-return asset and speaks in favor of including infrastructure in portfolios designed to have these properties. It is necessary to bear in mind that these values are calculated over the entire sample period. This does not, of course, exclude the possibility that some changes in these numbers within the considered sample path, may affect time-varying allocations.

Chekhlov et al. (2000) show that CDaR has appealing properties, such as convexity, with respect to portfolio positions, so that linear optimization algorithms can be applied to treat CDaR efficiently. Based on the sample path of the available assets, the optimization problem is formulated as minimizing portfolio drawdown risk, subject to constraints on the expected rate of return. Formally, this is given by

$$\min_{x} \Delta_{\alpha}(x_1,..., x_n)$$

Subject to

$$\sum_{i=1}^{n} \overline{r_i} x_i = \kappa \qquad \text{(I)}$$

$$0 \le x_i \le 1,\ i = 1,...,n \qquad \text{(II)}$$

$$\sum_{i=1}^{n} x_i = 1 \qquad \text{(III)}$$

Where $\overline{r_i}$ is the expected return on asset i.

Constraint (I) ensures that some predetermined expected portfolio return κ is met. Condition (II) imposes restrictions on the amount of wealth invested in one single asset (no short sales), and condition (III) guarantees that 100% of the available capital is invested. The reduction of the CDaR optimization problem to a linear programming problem is shown by Chekhlov et al. (2003) and is given in the appendix.

To account for time variation in asset behavior, we employ a dynamic asset allocation procedure. This means that we operate the optimization at each point in time (each month), starting in April 1996. Therefore, the first optimization covers the time frame from May 1990 to April 1996, a sample of 72 observations which is sufficient to obtain meaningful portfolio compositions. We then expand the time frame over which the optimization is performed by one month successively, until our analysis spans the entire time frame from May 1990 to July 2010, with efficient portfolio compositions from April 1996 to July 2010. This expanding window approach yields a time series of allocations for each asset. The optimization procedure thus accounts for changing asset characteristics over time and delivers more meaningful results than a static optimization procedure, which yields only one "optimal" value for each instrument in the portfolio.

At each point in time, we estimate ten efficient portfolios. These ten portfolios comprise the minimum CDaR portfolio (portfolio 1) and the maximum return portfolio (portfolio 10), as well as eight portfolios in between. We refer to portfolio 1-3 as low-return portfolios, portfolios 4-7 as medium return portfolios, and portfolios 8-10 as high-return. At each point in time, the return distance between two successive portfolios is equal (e.g. the difference in expected return between portfolios 2 and 1 is equal to the difference in expected return between portfolios 3 and 2, and so on). To check for robustness of our results, we perform the optimization in Section 4.1 with different specifications of the confidence parameter α. These are 0.99, 0.95, 0.90, 0.80 and 0.00. A confidence parameter of zero constitutes a limiting case of the CDaR risk function, which is the average drawdown. When α approaches one, the drawdown function accounts for one single event – the maximum portfolio loss compared to its previous value. For reasons of clarity, we mostly refer to the results for $\alpha = 0.95$ which constitutes a form of base case.

Although it is intrinsic to the CDaR concept to structure the optimization problem so that the return is maximized for a certain level of portfolio drawdown (because it is convenient for an investor to define the amount of wealth she is willing to risk), we fix an expected return and minimize the respective risk measure. This methodology has the advantage that, at each point in time, we cover the range of possible portfolio compositions from the MinCDaR portfolio to the maximum return portfolio. However, this means that the expected portfolio returns do not exactly match for the different models and for different points in time, which might impede comparability. Nevertheless, this methodology ensures that, for example, a MinCDaR portfolio is always compared to another MinCDaR portfolio. It would make no sense to compare portfolios which have identical levels of absolute return, because expected returns change over time. Furthermore, comparing portfolios with identical returns also creates the problem that one might choose a portfolio with an expected return below that of the MinCDaR portfolio. No rational investor would choose such a portfolio structure. Therefore, our approach guarantees that we always compare a low (medium, high) return portfolio to another low (medium, high) return portfolio and that we choose from a set of efficient portfolios.

6.4 Results

6.4.1 The Role of Infrastructure in Drawdown Efficient Portfolios

The allocations from different CDaR optimizations exhibit two general results. Firstly, as Table 4 indicates, infrastructure is on average mainly allocated to low and medium-expected return portfolios, and, secondly, as shown in Figure 2[4], infrastructure allocations vary significantly over time.

[4] The graphs for other confidence levels than 0.95 are provided in the appendix (Figures 3-6).

Figure 2: Time-Varying Infrastructure Allocations (α = 0.95)

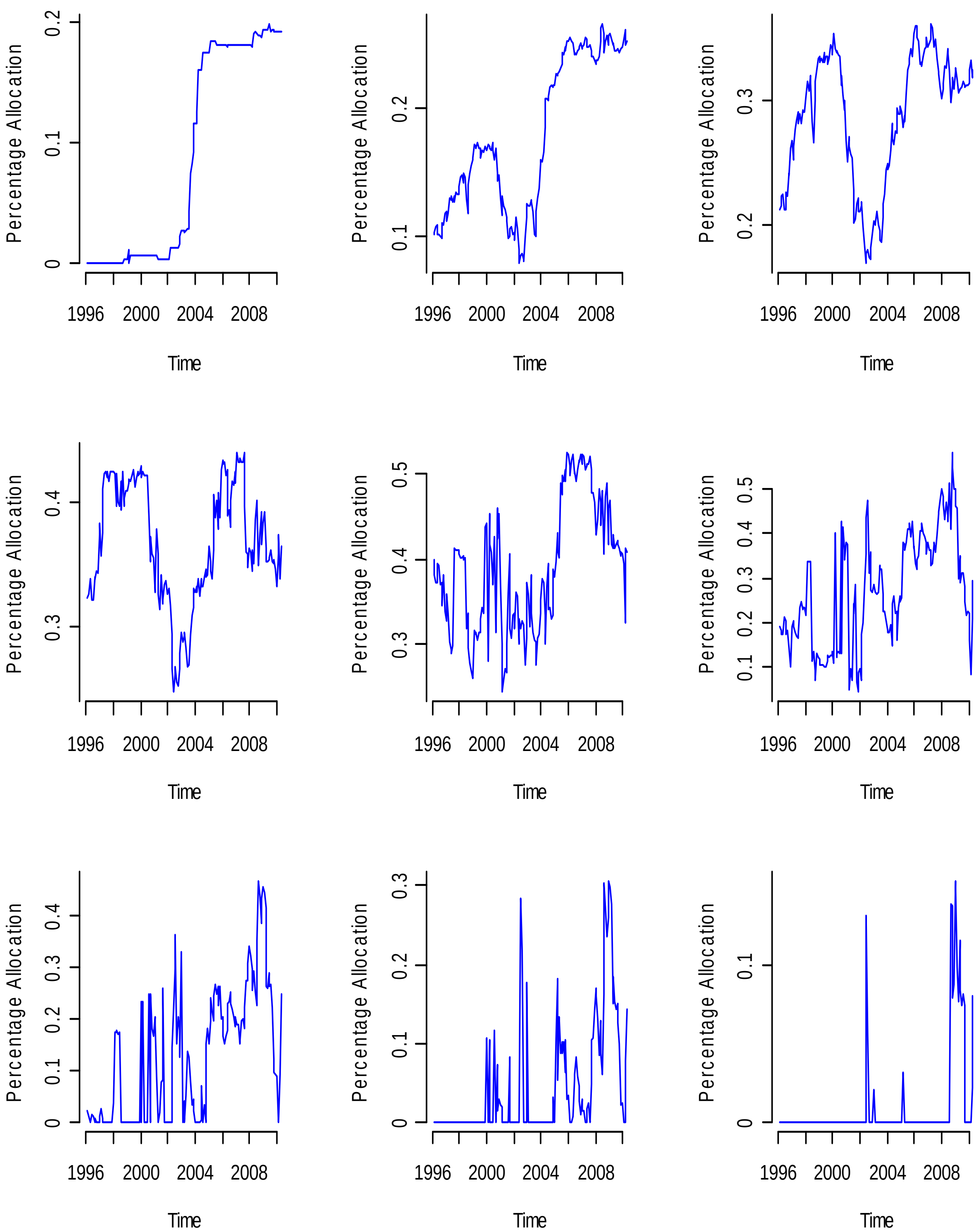


Table 4: Average Infrastructure Allocations April 1996 – July 2010

alpha	MinCDaR	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6	Portfolio 7	Portfolio 8	Portfolio 9	Portfolio 10
0.00	10%	21%	33%	42%	40%	34%	23%	13%	5%	0%
0.80	9%	20%	30%	37%	40%	34%	22%	12%	5%	0%
0.90	8%	17%	27%	35%	40%	34%	23%	12%	4%	0%
0.95	9%	18%	29%	37%	39%	27%	13%	4%	1%	0%
0.99	10%	20%	28%	32%	31%	21%	12%	6%	2%	0%

This table shows average infrastructure weights of the constructed portfolios from April 1996 – July 2010.

The upper left graph in Figure 2 depicts the allocation to infrastructure in portfolio 1, the graph to the right is the allocation to portfolio 2, and so on. The last graph shows infrastructure weights in portfolio 9. The allocation to portfolio 10 is not reported, as infrastructure plays almost no role.

The fact that infrastructure is, *on average,* primarily placed in low and medium-expected return portfolios derives from the simple fact that infrastructure investments exhibit moderate returns and low drawdown risk. This result applies independently of the chosen confidence parameter, as the absolute levels of average allocations do not vary much for a different α. Only for a confidence level of α = 0.99, one can observe a decrease in infrastructure weights in portfolios 3 to 8 compared to portfolios based on lower confidence levels. In this respect, the algorithm replaces infrastructure mainly by short and mid-term bonds, since these assets exhibit lower conditional drawdown risk in previous time periods.

When we analyze *time-varying* infrastructure allocations, we focus on portfolios 1 to 5. This is because we find a relatively clear distribution of infrastructure across time in these portfolios *and* the asset seems to play a major role. Let us, for example, have a closer look at drawdown-efficient portfolios when α is set to 0.95. Theoretical infrastructure weights rise to a maximum of 43% and the asset is – except for MinCDaR portfolios – consistently allocated over time. This implies that infrastructure plays an important role when the aim of an investor is to preserve his real capital, i.e. when reducing drawdown risk is at the center of his investment objectives. Not considering infrastructure therefore implies portfolio compositions which either have a higher drawdown risk for an identical return, or a lower expected return for the same level of drawdown risk[5].

However, we observe some inconsistency in allocations, which means that efficient infrastructure weights vary over time. From Figure 2, it is evident that infrastructure comprises

[5] The effect of the inclusion of infrastructure, i.e. the reduction in portfolio drawdown risk for various confidence levels is shown in the appendix in Table 10.

more than 40% (33%, 17%) of total wealth in portfolio 4 (3, 2) in March 2000. This allocation decreases rapidly to below 25% (17%, 8%) in August 2002, and recovers to almost 45% (37%, 26%) again throughout 2007. Since then, it remains quite stable. A similar allocation pattern holds for portfolio 5, although infrastructure weights recover faster during the impact of the dot.com crisis, and they are, on average, higher. The question rises, as to why the allocation to infrastructure decreases with the dot.com bubble in March 2000 and is followed by a sharp increase some years later. The fact that the allocation to infrastructure decreases along with the decline in the equity market seems to be rather counterintuitive, as one assumes that losses in the equity market (the average monthly loss of the S&P 500 is 1.64% between March 2000 and August 2002) induce an increase in the attractiveness of relatively conservative assets like infrastructure. However, instead of infrastructure, the algorithm allocates short-term corporate bonds and cash. The reason is simple; the average drawdown risk of infrastructure increases as a result of relatively low returns, while the opposite applies to short term corporate bonds and cash. This example shows that a bear market for equities does not necessarily advocate the inclusion of infrastructure, but short-term assets, such as AAA-rated corporate bonds and money market instruments, are rather preferred. A period of rising infrastructure weights again begins in Q4 2003. This is especially evident in the MinCDaR portfolio, where infrastructure is included, although this portfolio had previously been dominated by cash. The inclusion of infrastructure, at the cost of cash, is a general result in low-return portfolios and explains rising infrastructure weights. From Q3 2003 onwards, the average drawdown risk of cash increases[6], while that of infrastructure decreases contemporaneously. The levels of drawdown risk persist to the end of the period under examination and explain the stable proportion of infrastructure up to July 2010. Although, there are some differences in absolute infrastructure weights when the confidence parameter is changed to 0.00, 0.80 or 0.90, the results remain qualitatively unchanged and the conclusion that infrastructure constitutes a viable asset for low to medium-return portfolios – in which it is consistently allocated – persists. Only for an extreme value of $\alpha = 0.99$, can one observe a substitution of infrastructure by short-term government bonds and cash over the course of the Lehman collapse.

Allocations in portfolios 6 and 7 are highly volatile and strongly reliant on whether mid/long-term bonds or equities are allocated. Depending on the return information available at a given point in time, either infrastructure or mid/long-term bonds or equities are placed in the portfolio. For example, after September 2008, infrastructure weights decrease remarkably, but mid-

[6] The increase in the drawdown risk of cash is might come from the increase in unexpected inflation. We employ the approach of Fama and Schwert (1977), to proxy for unexpected inflation, and find that unexpected inflation is negatively related to the returns on cash, and that unexpected inflation increases from 2002 to 2004. This induces a contemporaneous decrease in the return on cash and an increase in drawdown risk.

term government bonds enter the portfolio. Especially the volatility of equity returns entails volatile portfolio compositions with no such consistent allocation patterns, as in lower-return portfolios. It is therefore difficult to make a general statement on the role of infrastructure. Although its average allocation is not particularly low, the asset is, as a logical consequence of moderate returns, not as heavily allocated as in lower-return portfolios. Contrary to the findings for lower-return portfolios, the allocation to infrastructure is sensitive to the confidence level, when the expected return increases. When α is set to lower values, such as 0.00, 0.80 or 0.90, infrastructure is allocated consistently to portfolios 6 to 9 before 2001, while it (almost) disappears, when α is set to 0.95 and 0.99. As already stated, there is a tendency to average out extreme drawdowns for lower levels of α, while a higher confidence parameter, in contrast, tends to account only for very extreme outcomes. This leads to the exclusion of infrastructure before 2001, and to the inclusion of mid-term government bonds, as their 0.99-CDaRs are smaller than those of infrastructure. However, this tendency reverses when α is set to 0.00. These inconsistent results make it impractical to make a general recommendation on the role of infrastructure in portfolios which aim at yield high expected returns, but efficient weights largely depend on the perception of risk.

It should be noted that the presented allocations are extreme outcomes and constitute corner solutions. In reality, fund managers are restricted, either institutionally or through regulatory issues, in allocating wealth to various assets. To reflect this situation, we impose restrictions on portfolio weights. We assume that a representative fund manager has to allocate at least 20%, but not more than 40%, to long-term government bonds and large cap stocks, respectively. Furthermore, in the interest of diversification, no asset, apart from long-term government bonds and large cap stocks, is allowed to exceed a proportion of more than 20% of total wealth. At least 5% of all funds must be allocated to cash, with a maximum allocation of 15%. The average portfolio weights for various levels of α are given in Table 5 and show that infrastructure is a viable asset for portfolio performance, especially in low and medium- return portfolios, but decreases with rising expected returns.

Table 5: Average Constrained Infrastructure Allocations April 1996 – July 2010

alpha	MinCDaR	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6	Portfolio 7	Portfolio 8	Portfolio 9	Portfolio 10
0.00	20%	19%	17%	14%	11%	10%	9%	8%	5%	0%
0.80	18%	19%	18%	15%	13%	12%	10%	8%	4%	0%
0.90	20%	20%	19%	18%	16%	14%	12%	8%	4%	0%
0.95	19%	19%	19%	19%	17%	15%	12%	8%	2%	0%
0.99	18%	19%	19%	18%	17%	14%	10%	7%	2%	0%

This table shows average constrained infrastructure weights of the constructed portfolios from April 1996 – July 2010

As a result of the constraints imposed on portfolio weights, the allocation to infrastructure is not as heavy as in unrestricted portfolios, but large cap stocks, long-term government bonds and some cash is placed instead. Only the MinCDaR portfolio contains a higher average proportion of infrastructure, which is a consequence of the restriction on cash. Again, it is important to note that portfolios which are constructed under different constraints are not comparable one to one. While, for example the constrained MinCDaR portfolio exhibits a monthly average return of 0.46%, a comparable return level (0.48%) is obtained from portfolio 5, when asset weights are not constrained. Nevertheless, constrained portfolio compositions, which may reflect institutional investment policy more accurately, deliver results indicating that the inclusion of infrastructure offers clear advantages for portfolio managers, especially in lower return portfolios. This confirms previous findings.

6.4.2 Infrastructure, Pension Liabilities and Target Rate Relative Drawdown Risk

The objective of many investors is not simply to minimize portfolio risk for some given level of expected return, but to accumulate assets which are able to meet their future liabilities (for example, insurance companies or pension funds) or some pre-specified target return which is required by their equity or debt investors. Such a strategy places liabilities or some benchmark return at the center of the investment policy, making it the reference point for evaluating portfolio risk and performance. The concept of drawdown risk is likely to meet these objectives, as it is able to address investor concerns of falling short of these rates.

Pension liabilities can be replicated by certain liability indices, such as the Markit iBoxx US Pension Liability Index series, which is available from Q1 1998 onwards, as well as the Citigroup Pension Liability Index, which starts in Q1 1995. However, none of these indices covers the entire sample period of this study. To overcome this problem, we apply the methodology of Hovenaars, Molenaar, Schotmann and Steenkamp (2008) in constructing a pension liability index. Their approach is based on a log-linear transformation process, and the construction of liability returns $r_{L,t+1}$ is given as follows

$$r_{L,t+1} = \frac{1}{12} rr_{t+1} - D_L (rr_{t+1} - rr_t) \qquad (7)$$

where rr_t is the 10 Year Treasury Yield adjusted to constant maturity and D_L the duration of pension fund liabilities. As in Hoevenaars et al. (2008)[7], an average duration of 17 years is assumed[8]. This self-constructed series is significantly related to the Markit, as well as the Citigroup series, with statistically significant (1%) correlations of 0.65 and 0.44, respectively. This makes it an appropriate tool for depicting liability performance, which is used in the further course of our analysis. To construct liability efficient portfolios, we employ the same methodology as before and now minimize liability relative drawdown risk (α = 0.95)[9], while achieving some excess return over liabilities.

The constructed portfolios are dominated by long-term government bonds in low and medium-return portfolios. When higher returns have to be achieved, large cap stocks are allocated at earlier time moments and are, from 2001 onwards, mainly replaced by better performing small cap stocks. In terms of infrastructure weights, we obtain a rather unexpected result. In contrast to the findings in Section 4.1, infrastructure is not included in any efficient portfolio, regardless of the expected portfolio return, the confidence level and the time moment. Where does this result come from? The valuation of pension liabilities is at the very core of this outcome. Pension liabilities are valued simply by discounting the cash flow of future pension payments via daily available government bond spot curves or swap quotations. As liabilities are usually retained for a long time before they are distributed to the beneficiaries, this places them at the long end of the yield curve and renders their values sensitive to changes in interest rates and other changes in the yield curve. This inherently links the return on pension liabilities to the returns on long term (government) bonds. A significant fall in interest rates, such as during the recession in 2008, therefore has a dramatic impact on the value of pension liabilities, with an increases of almost 20% in value. No other asset apart from long term (govern-

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[7] The data/methodology used is subject to the condition of constant age groups and pension rights accrued per group over time. The assumption that the pension fund is in a stationary state allows us to describe liabilities as a constant maturity index-linked bond. We further assume that the inflow from pension contributions is equal to the NPV of new liabilities and the current payments of the fund, and additionally ignore taxation issues, demographics and longevity risk. In consequence, interest rate and inflation risk are the only factors which are relevant to the pension scheme.

[8] To check for robustness, we apply different durations to construct liabilities, namely 15, 16, 18 and 19 years. The results, however, do not change fundamentally and are available from the authors upon request.

[9] We checked for robustness by employing confidence levels of 0.99, 0.95, 0.80 and 0.00.

ment) bonds can match such an increase in value and makes other assets less attractive from a liability point of view.

Table 6: Relation of Monthly Asset Returns with Liabilities May 1990 – July 2010

	STGovBonds	MTGovBonds	LTGovBonds	STCorpBonds	MTCorpBonds	LTCorpBonds	Cash	Small Caps	Large Caps	Infrastructure
Correlation	0.56	0.58	0.58	0.49	0.52	0.52	0.25	-0.29	-0.18	0.00
Beta	0.11	0.17	0.42	0.11	0.17	0.35	0.02	-0.44	-0.21	0.00

The correlations and betas of liabilities[10] with other assets, as shown in Figure 6, underpin this finding and provide – together with the high expected return on long term government bonds – a rationale for significant long term government bond allocations in liability-efficient portfolios. If the return on an asset is sufficiently high, and moves together with the return on liabilities, it is a viable asset for minimizing liability-relative drawdown risk. Equities are, on average, included, as they offer high expected returns, especially in former years. The reason, why drawdown-efficient portfolios do not contain any infrastructure is straightforward. Firstly, infrastructure returns are lower than those of small caps, large caps and long term government bonds and, secondly, infrastructure does not move together with liabilities, which is also not favorable from a drawdown perspective. This contradicts the reputation of infrastructure as an appropriate asset for pension plan liability matching.

In addition to the liability-driven approach, we benchmark each asset against a fixed target return. Since investors are not homogenous, but have different investment objectives, we consider three different real target returns. These are 2.0%, 3.0% and 4.0% annually. One has to bear in mind that the applied target rates should not be confused with expected returns. While the expected return reflects the return an investor aims to achieve, the target rate is essential for the definition of risk and reflects some level of return, to which the investor is averse to falling short. Therefore, it is not a contradiction to assume an expected return which exceeds the target rate.

[10] The monthly real average return on the liabilities is 0.61%, and the standard deviation is 3.79%. We compare the return and the standard deviation of our self constructed liability series to the Citigroup and the Markit series over matching intervals and find quite similar numbers. While, for example, our series exhibits a nominal return and a standard deviation of 0.71% and 3.77% over the January 1995 to July 2010 period, the corresponding values for the Citigroup series are 0.87% and 3.95%.

Table 7: Average Infrastructure Allocations (α = 0.95) April 1996 - July 2010

Target p. a.	MinCDaR	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6	Portfolio 7	Portfolio 8	Portfolio 9	Portfolio 10
2.00%	30%	37%	42%	43%	33%	20%	9%	3%	1%	0%
3.00%	44%	45%	46%	40%	28%	16%	8%	2%	0%	0%
4.00%	49%	49%	43%	33%	23%	13%	5%	1%	0%	0%

This table shows average infrastructure weights of the constructed portfolios from April 1996 – July 2010 for different target rates.

The average portfolio compositions for different targets are presented in Table 7. In accordance with the results from Section 4.1, we find that infrastructure is, on average, present in low and medium-return portfolios across all target returns. The allocation to infrastructure is higher than in the base model in Section 4.1 and increases with rising target rates in low-return portfolios, a result which contradicts intuition. However, this outcome can easily be explained by the fact that infrastructure replaces cash. This effect becomes more pronounced the higher the target return is set. The fact that the allocation towards cash diminishes with rising target rates is intuitive. An increase in the target return raises the drawdown risk of cash as a result of relatively low returns, and provides momentum for including an asset which exhibits higher returns, but moderate drawdown risk – a role played by infrastructure. When the expected return increases, infrastructure is removed more from the portfolio than in our base case; as a logical consequence of relatively low infrastructure returns, this pattern is more conspicuous, the higher the target rate is set. These findings confirm the results from Section 4.1 and accentuate the role of infrastructure as a viable asset for low-risk portfolios, when investors exhibit different target rates of return.

Figure 7: Time-Varying Infrastructure Allocations (α = 0.95) Target = 2

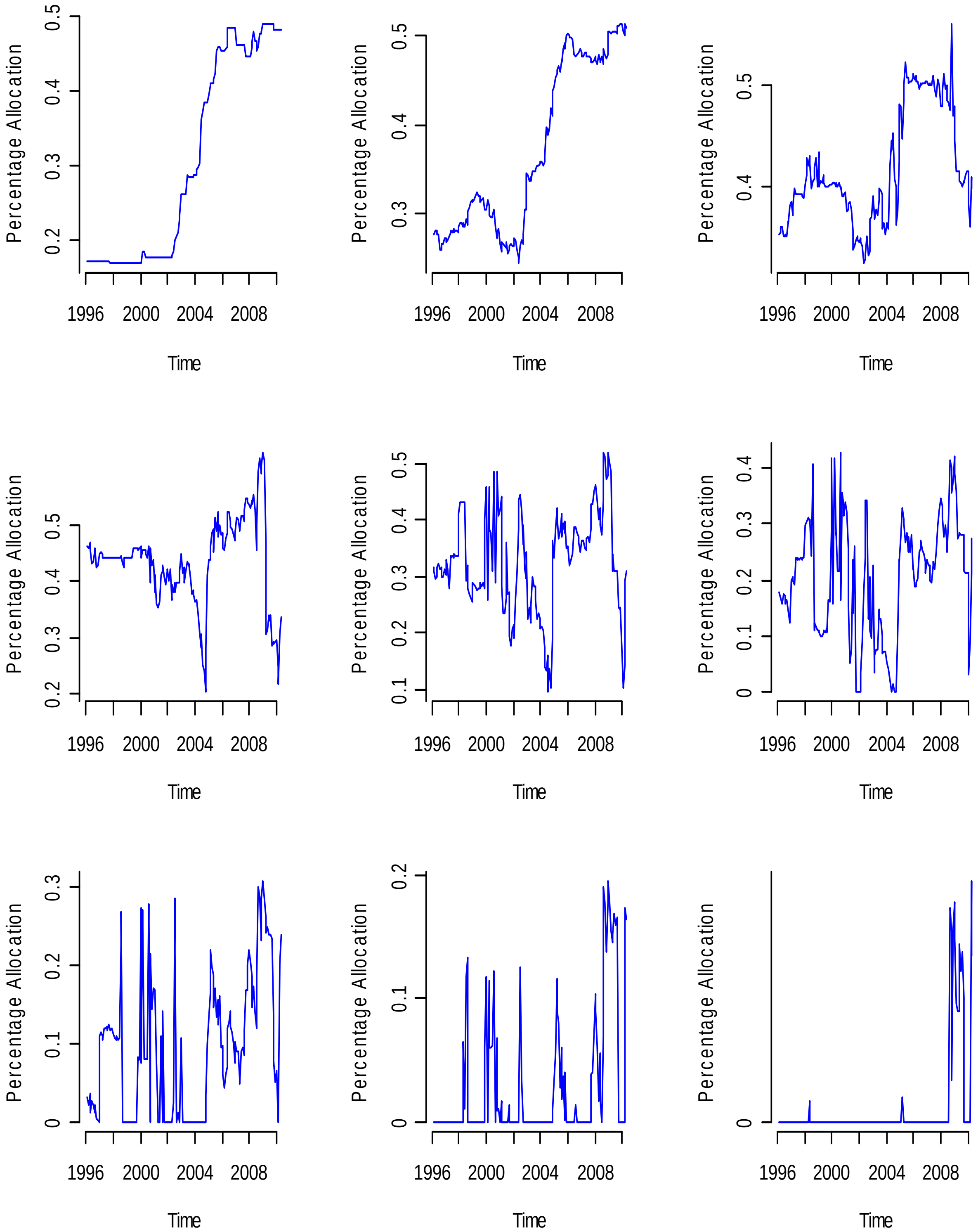


Figure 8: Time-Varying Infrastructure Allocations (α = 0.95) Target = 3

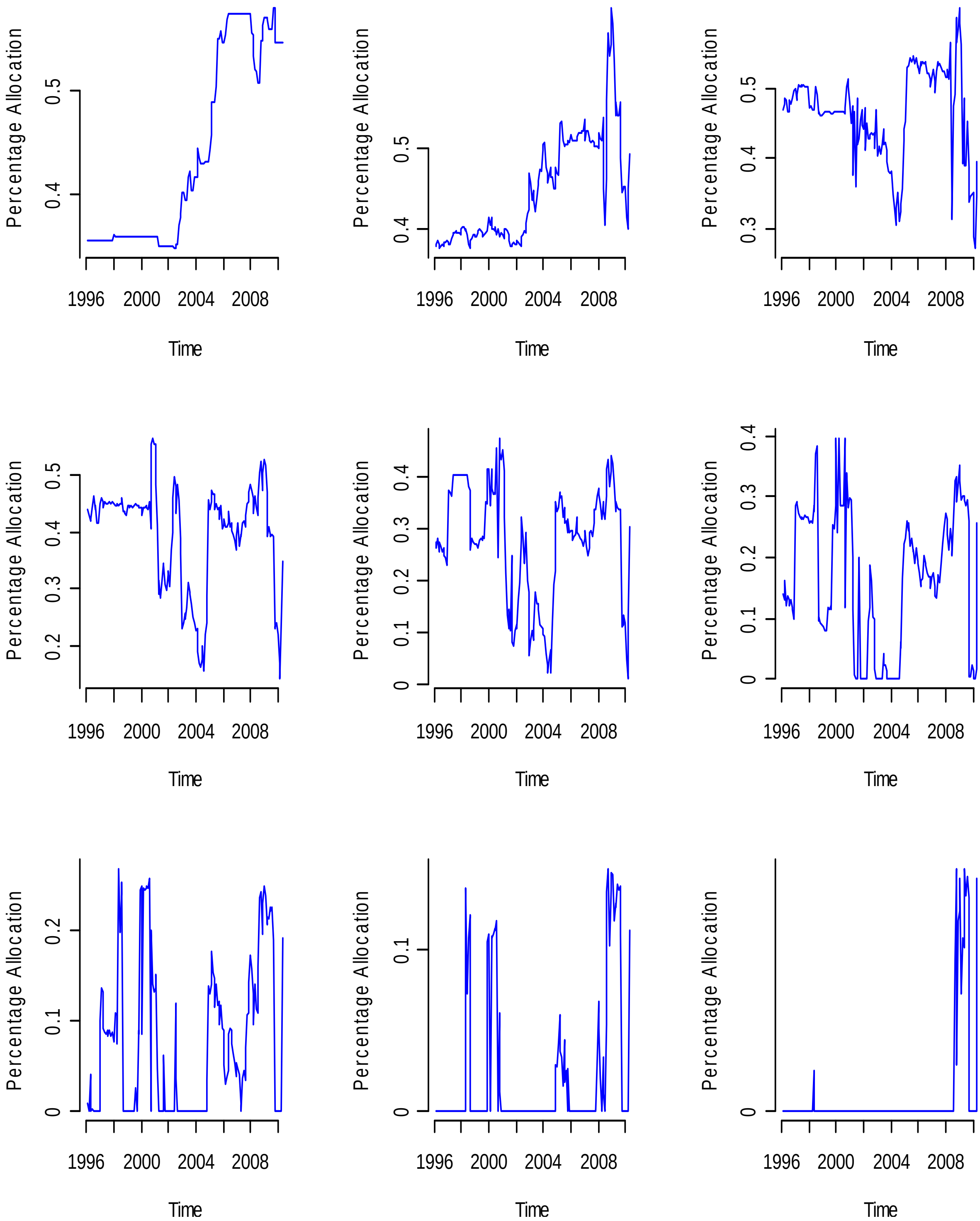
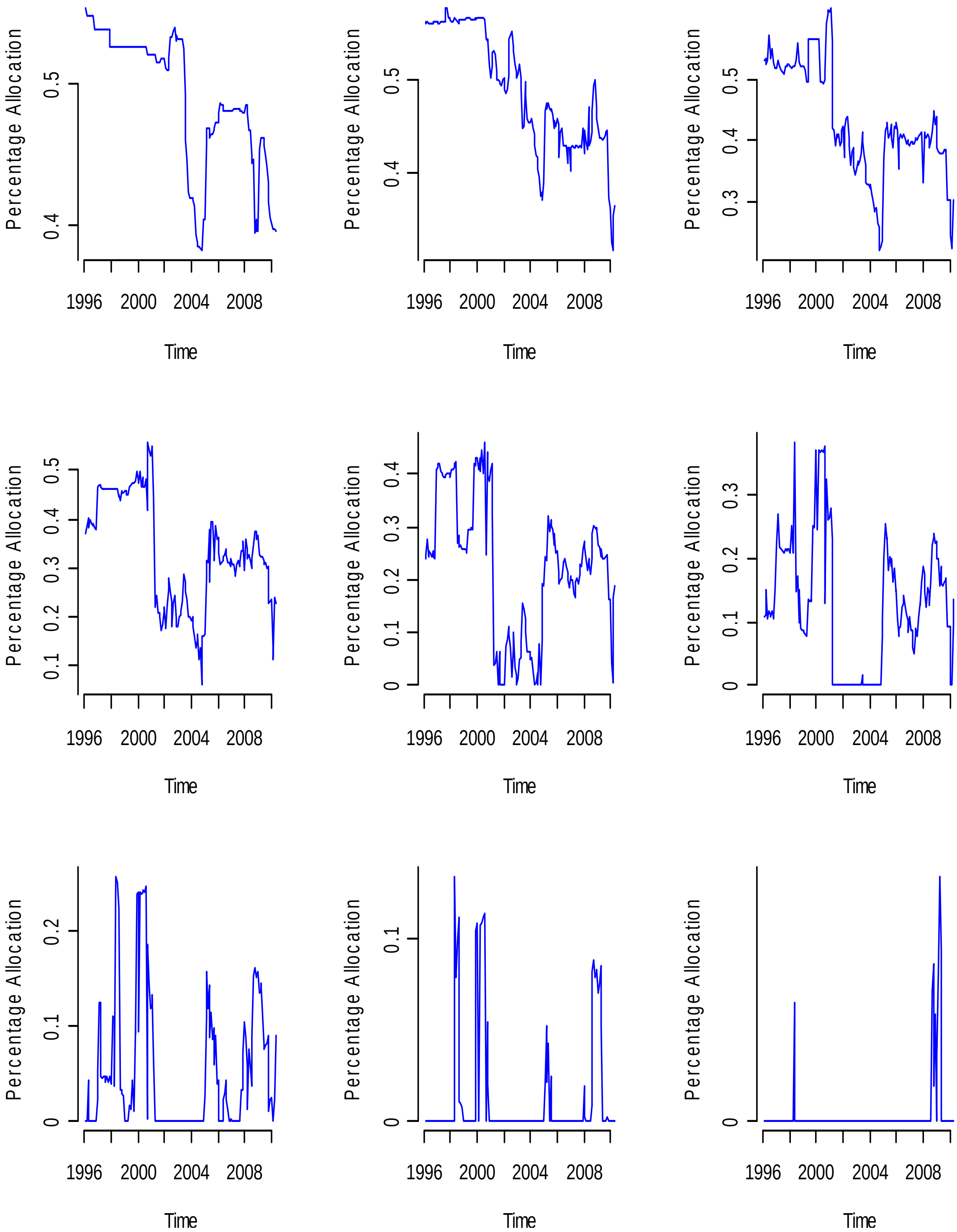


Figure 8: Time-Varying Infrastructure Allocations (α = 0.95) Target = 4



In accordance with our previous findings, infrastructure allocations vary over the time horizon, as shown in Figure 7 to 9. The volatility of infrastructure weights increases with an increase in the expected return and in the target rate. As a result of implementing the target return, infrastructure allocations are not as sensitive to short-term bonds, but rather to mid-term (corporate and government) bonds. This result makes sense, as short-term investments become – due to their low expected returns – more unattractive from a target-rate perspective. This sensitivity can be observed over the course of the dot.com and the recent financial crisis, with infrastructure being replaced by mid-term bonds, especially for medium and some higher -return portfolios. Nevertheless, the picture of infrastructure as an asset which is able to contribute mainly to the performance of low-risk and low-return portfolios is clearly evident, as the asset is stable and persistently allocated to those portfolios. Since it tends to replace cash, infrastructure is now allocated to the MinCDaR portfolio across the entire time horizon. Furthermore, infrastructure weights are more stable in low-return portfolios when a benchmark is implemented.

6.4.3 Downside Beta Hedged Portfolios

Ang, Chen and Xing (2006) show that investors demand a premium on equities which move together with the market when it drops. To incorporate this aversion to (equity) market downside risk, we construct portfolios which do not follow the equity market when it is in a poor state – expressed simply, a restriction on portfolio downside beta. We define portfolio downside beta as the weighted sum of individual assets' downside betas. Accordingly, this is given by

$$\beta_p^- = \sum_{i=1}^{n} \beta_i^- x_i \tag{9}$$

Following Ang et al. (2006), we define individual asset downside beta as

$$\beta_i^- = \frac{\operatorname{cov}(r_i, r_m \mid r_m < 0)}{\operatorname{var}(r_m \mid r_m < 0)} \tag{10}$$

where r_m is return on the S&P 500. This means that we calculate beta only over those periods when the broad real equity market return is below zero. Average downside betas for different assets are shown in Table 8.

Table 8: Average Downside Betas with the S&P 500 May 1990 – July 2010

STGovBonds	MTGovBonds	LTGovBonds	STCorpBonds	MTCorpBonds	LTCorpBonds	Cash	Small Caps	Large Caps	Infrastructure
0.05	0.11	0.36	0.06	0.13	0.31	-0.01	1.27	0.99	-0.07

While infrastructure returns are negatively related to equity market down movements, long-term bonds and especially equities, are exposed to higher systematic downside risk. To construct downside beta hedged portfolios, we impose a further constraint in the optimization problem, which ensures that portfolio downside beta does not exceed a specific, pre-determined value, which is set to 0.4 and 0.2, respectively. Table 9 shows average infrastructure weights for downside beta hedged portfolios.

Table 9: Downside Beta Hedged Infrastructure Allocations April 1996 – July 2010

Downside Beta Restriction = 0.4										
alpha	MinCDaR	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6	Portfolio 7	Portfolio 8	Portfolio 9	Portfolio 10
0.00	10%	19%	26%	34%	38%	34%	30%	25%	21%	16%
0.80	9%	17%	25%	31%	36%	36%	29%	23%	19%	16%
0.90	8%	15%	21%	29%	36%	37%	30%	23%	18%	16%
0.95	9%	15%	23%	30%	37%	39%	32%	23%	15%	16%
0.99	10%	17%	23%	30%	34%	33%	29%	21%	14%	16%
Downside Beta Restriction = 0.2										
alpha	MinCDaR	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6	Portfolio 7	Portfolio 8	Portfolio 9	Portfolio 10
0.00	10%	17%	24%	31%	34%	30%	28%	27%	24%	22%
0.80	9%	16%	23%	29%	32%	33%	29%	26%	24%	22%
0.90	8%	14%	19%	26%	32%	35%	31%	26%	24%	22%
0.95	9%	14%	20%	27%	33%	36%	32%	28%	25%	22%
0.99	10%	16%	21%	27%	31%	32%	31%	29%	26%	22%

It is not surprising that the average share of equities decreases in downside beta (0.4) hedged portfolios, as the downside beta is calculated conditionally on an equity market return series. To achieve higher expected returns, long-term government bonds are partially allocated instead. Infrastructure weights are higher in those portfolios which are intended to yield high returns, compared to non-hedged portfolios. These high allocations in higher return portfolios are associated with the ability of infrastructure to diversify systematic equity risk. When, for example, the proportion of small caps rises in mid 2005, the allocation to infrastructure rises simultaneously. Therefore, if investors wish to earn relatively high returns, but have an aversion towards systematic equity downside risk, they would be well advised to allocate some of their capital to infrastructure, along with equities. However, when long-term government bond returns increase over the course of the financial crisis and begin to enter high-return portfolios in place of equities, the importance of infrastructure for diversifying systematic equity risk decreases, as bonds themselves do not exhibit as high a downside beta as equities. Therefore, the weight of infrastructure, especially in high-return portfolios, depends on the relative weights of bonds and equities. If an investor intends to invest in equities, she is advised to devote some capital to infrastructure for diversification reasons, although this does not apply when the main investment asset is fixed income. In contrast to high-return portfolios, the average proportion of infrastructure decreases in low-return and some medium-return portfolios, but cash and some short-term corporate bonds are used instead.

Figure 10: Time-Varying Infrastructure Allocations (α = 0.95) Downside Beta Restriction= 0.4

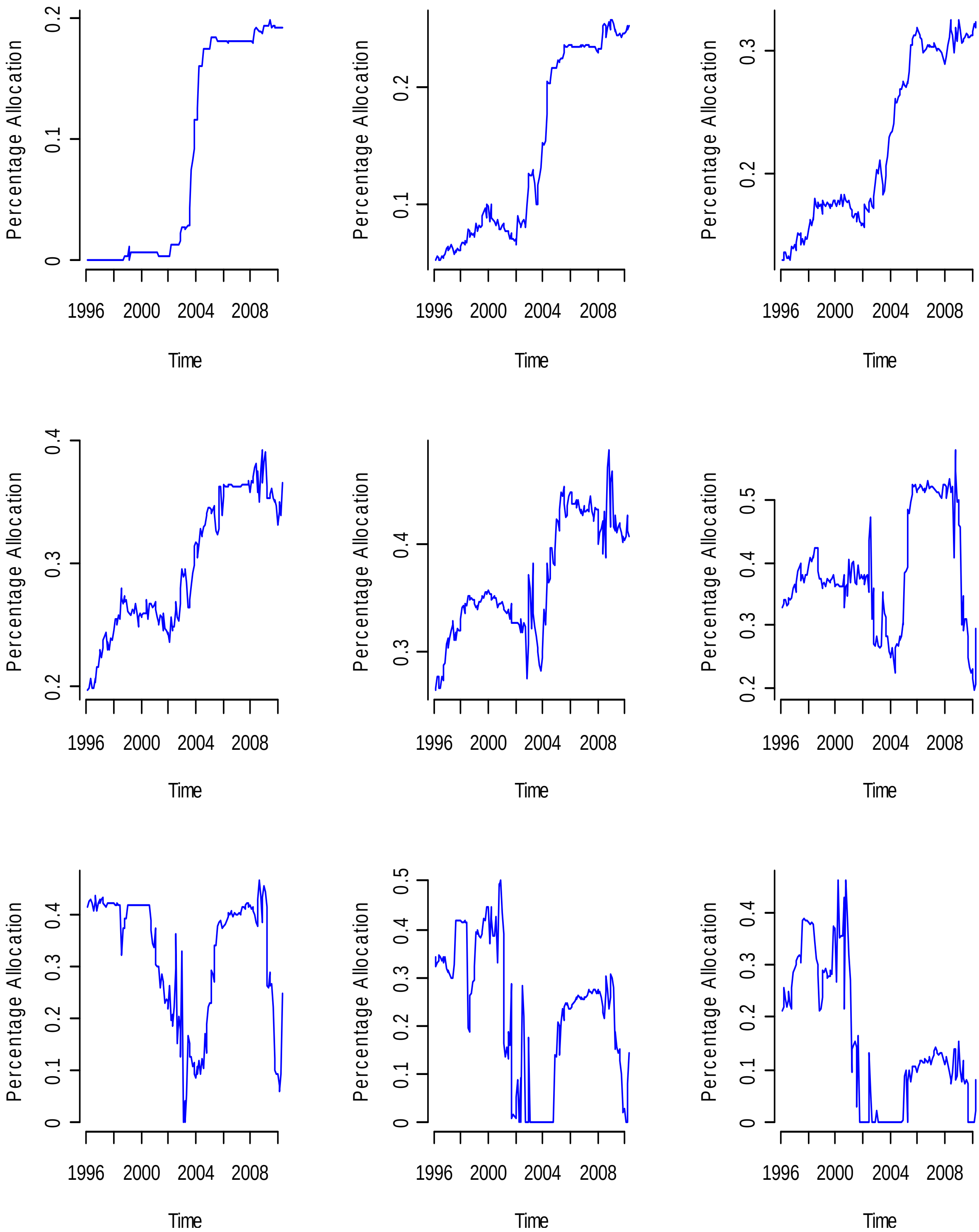
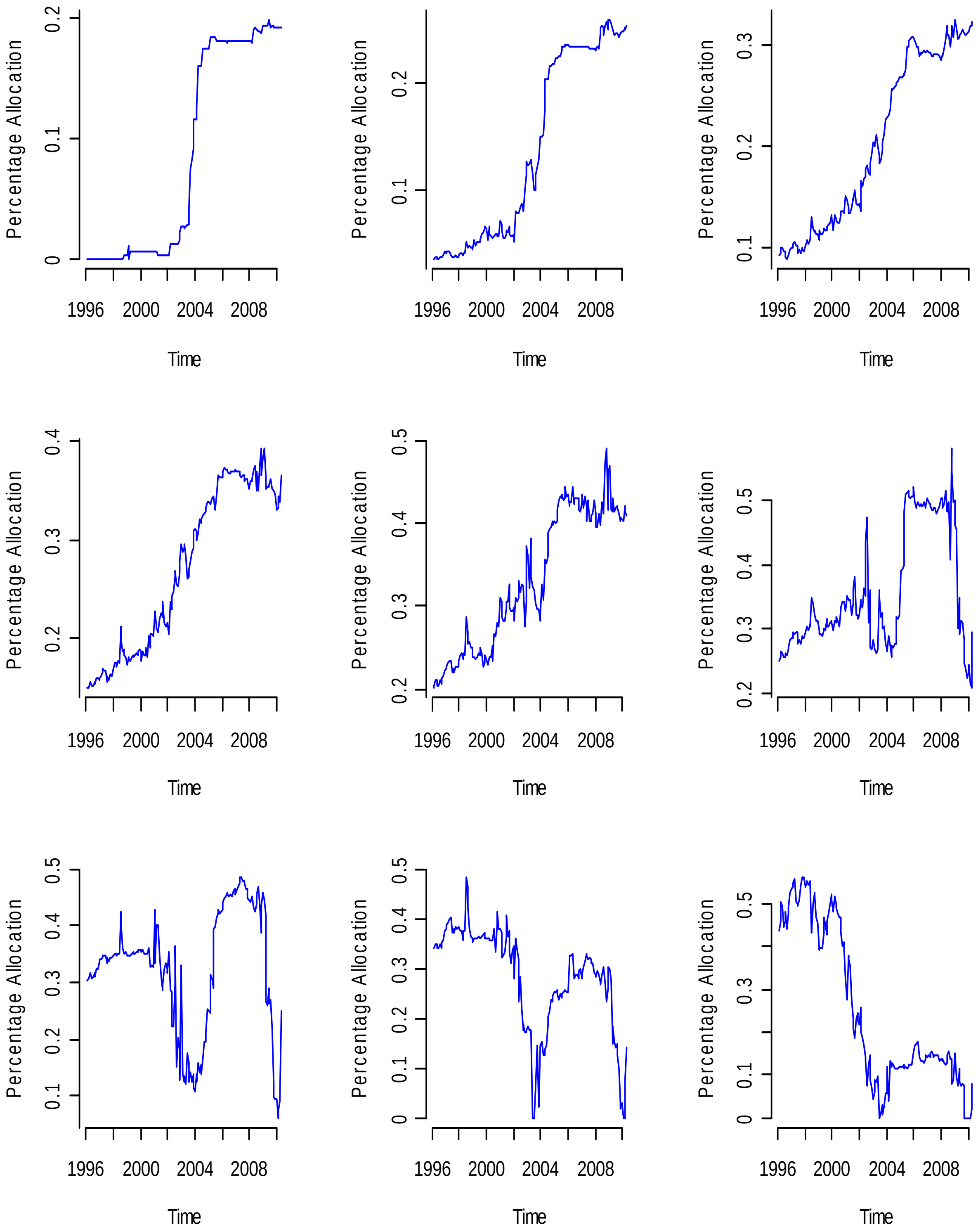


Figure 11: Time-Varying Infrastructure Allocations (α = 0.95) Downside Beta Restriction = 0.2



In terms of time-varying asset weights, as shown in Figures 10 and 11, one can further see similar, but smoother sequences of allocations, compared to when portfolios are not downside beta hedged. This results from low downside beta for infrastructure with respect to the equity market and implies that infrastructure is an attractive asset for hedging declines in the equity market. When the restriction on beta is altered to 0.2, the presented results do not change fundamentally, but are more accentuated, which means that the allocation to infrastructure is even lower in low return portfolios, but increases with higher expected returns.

6.5 Conclusion

Direct infrastructure has emerged as a separate asset during recent years and it is now finding its way into institutional investment portfolios. However, the role of direct infrastructure in mixed asset portfolios is, due to data limitations, a barely investigated topic and the question arises as to how much infrastructure is "optimal". This study aims to fill this research gap, by assessing a row of asset allocation models which reflect the attitudes of different investors. To mirror direct infrastructure performance, we employ a transaction-based index which is provided by CEPRES. The proposed risk measure is the Conditional Drawdown at Risk (CDaR) which was introduced by Chekhlov et al. (2000, 2003, 2005). This measure of portfolio risk is defined as a decline in uncompounded portfolio value, compared to the maximum value attained in the previous moments on a sample path. To account for time-varying asset characteristics, we employ a dynamic asset allocation procedure, which estimates efficient asset weights at each point in time. We firstly minimize CDaR for some given levels of expected returns in unconstrained portfolios, which contain government and corporate bonds of different maturities, cash, small cap as well as large cap stocks and infrastructure. In a second step, to be more in line with the actual behavior of fund managers, we also perform the optimization with restrictions on asset weights. Moreover, we investigate the role of infrastructure when pension liabilities and various predefined target returns are the reference point for evaluating portfolio risk and performance. The final model assumes that portfolio managers are averse towards systematic equity market downside risk and imposes a restriction on downside beta when structuring efficient portfolios.

Our results show that infrastructure is allocated significantly to low and medium-return portfolios and that infrastructure allocations vary over time. These results are independent of the particular model. We find that infrastructure does not prove to be a good hedge against pension liabilities, but traditional assets such as small caps, large caps and long term government bonds are preferable. This outcome might be associated with the modeling of pension liability returns, which are strongly related with the returns on long-term bonds. The role of infrastructure in a liability framework, especially in consideration of longer holding periods, may constitute a promising topic for further research.

When asset returns are targeted against some predetermined benchmark to mirror capital cost, the role of infrastructure in low-risk portfolios is even more accentuated. Due to the inability of cash to achieve higher return targets, infrastructure is weighted more heavily.

As infrastructure does not correlate with equity returns in down markets, it proves to be a valuable hedge against downside systematic risk which also results in portfolio compositions that exceed those in current investment portfolios.

The proposed models do not demonstrate exactly how much infrastructure should be allocated to a multi-asset portfolio, as this depends on various parameters, such as the investor's expected return, her perception of risk, some target return or the market phase. Furthermore, our results do, not necessarily suggest that investors should reallocate their portfolios and increase their allocation to infrastructure, as we also do not know exactly how much infrastructure is already allocated. However, there are many indications that the actual proportion of infrastructure is, on average, below that suggested by our models.

In summary, we find stable and conclusive evidence that infrastructure can contribute to portfolio performance, especially in low and medium-return portfolios, and that the inclusion of infrastructure may deliver a better risk-return tradeoff than conventional portfolio allocations, which comprise mainly stocks and bonds. This insight should be especially useful for investors whose aim is not to earn superior returns, but to protect their portfolios from extreme declines in value.

6.6 Appendix

The optimization problem in which drawdown risk is minimized for a certain level of expected return at each point in time is reduced to the following linear programming problem.

$$
\begin{aligned}
& Minimize\,(in\, x, u, z, \eta)\; z \\
& s.t. \\
& \eta + \frac{1}{(1-\alpha)J}\sum_{k=1}^{J} z_k \le z \\
& z_k \ge u_k - y_k * x - \eta \quad 1 \le k \le J \\
& z_k \ge 0 \quad 1 \le k \le J \\
& u_k \ge y_k * x \quad 1 \le k \le J \\
& u_k \ge u_{k-1} \quad 1 \le k \le J \\
& u_0 = 0 \\
& R(x) = \kappa \\
& 0 \le x_i \le 1 \\
& \sum_{i=1}^{n} x_i = 1,
\end{aligned}
$$

where y_k is a vector of cumulative asset returns up to the time moment k, x is a vector of portfolio weights, and z_k as well as $u_k, 1 \le k \le J$ are auxiliary variables. κ is a predetermined value for the return on the portfolio $R(x)$.

Figure 3: Time-Varying Infrastructure Allocations (α = 0.00)

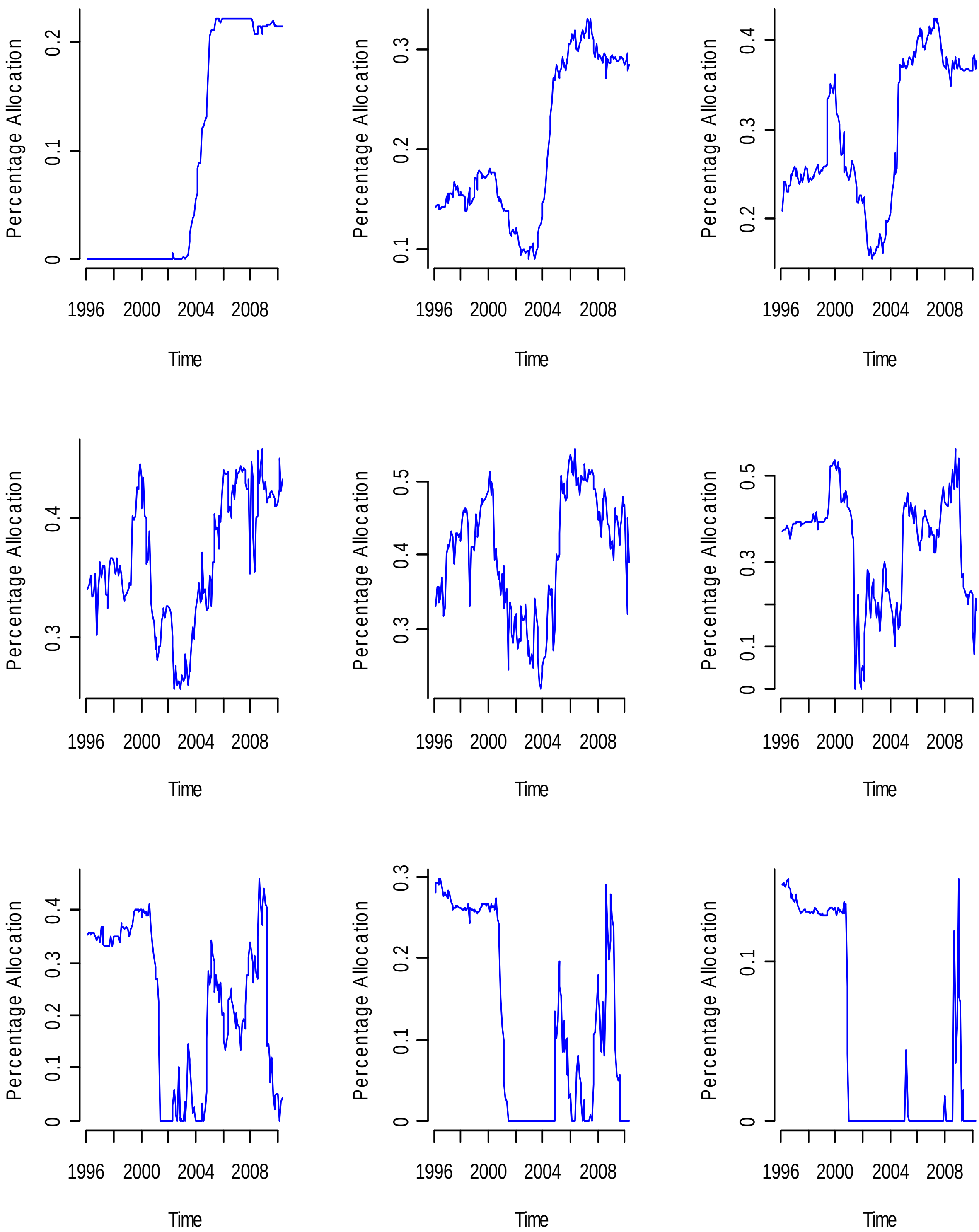


Figure 4: Time-Varying Infrastructure Allocations (α = 0.80)

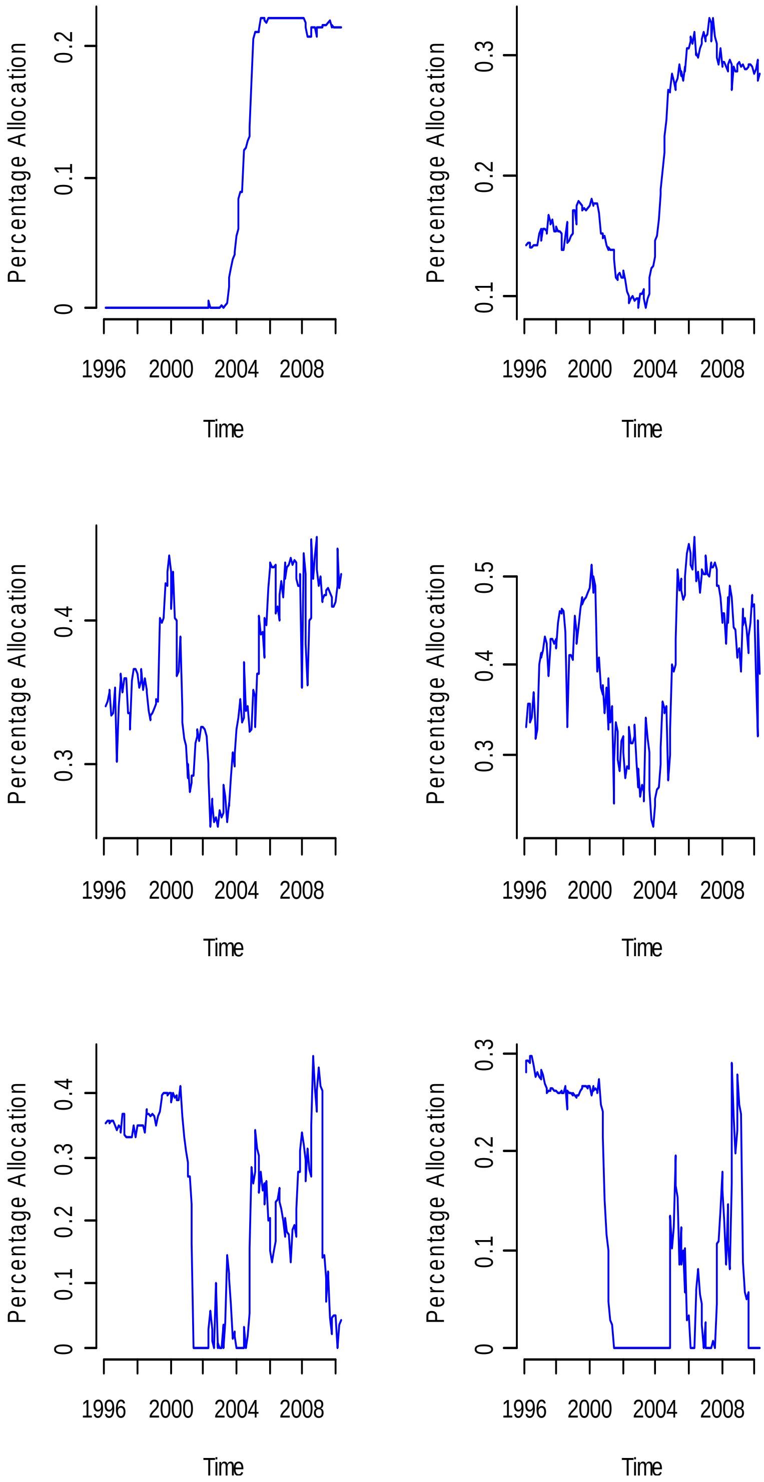


Figure 5: Time-Varying Infrastructure Allocations (α = 0.90)

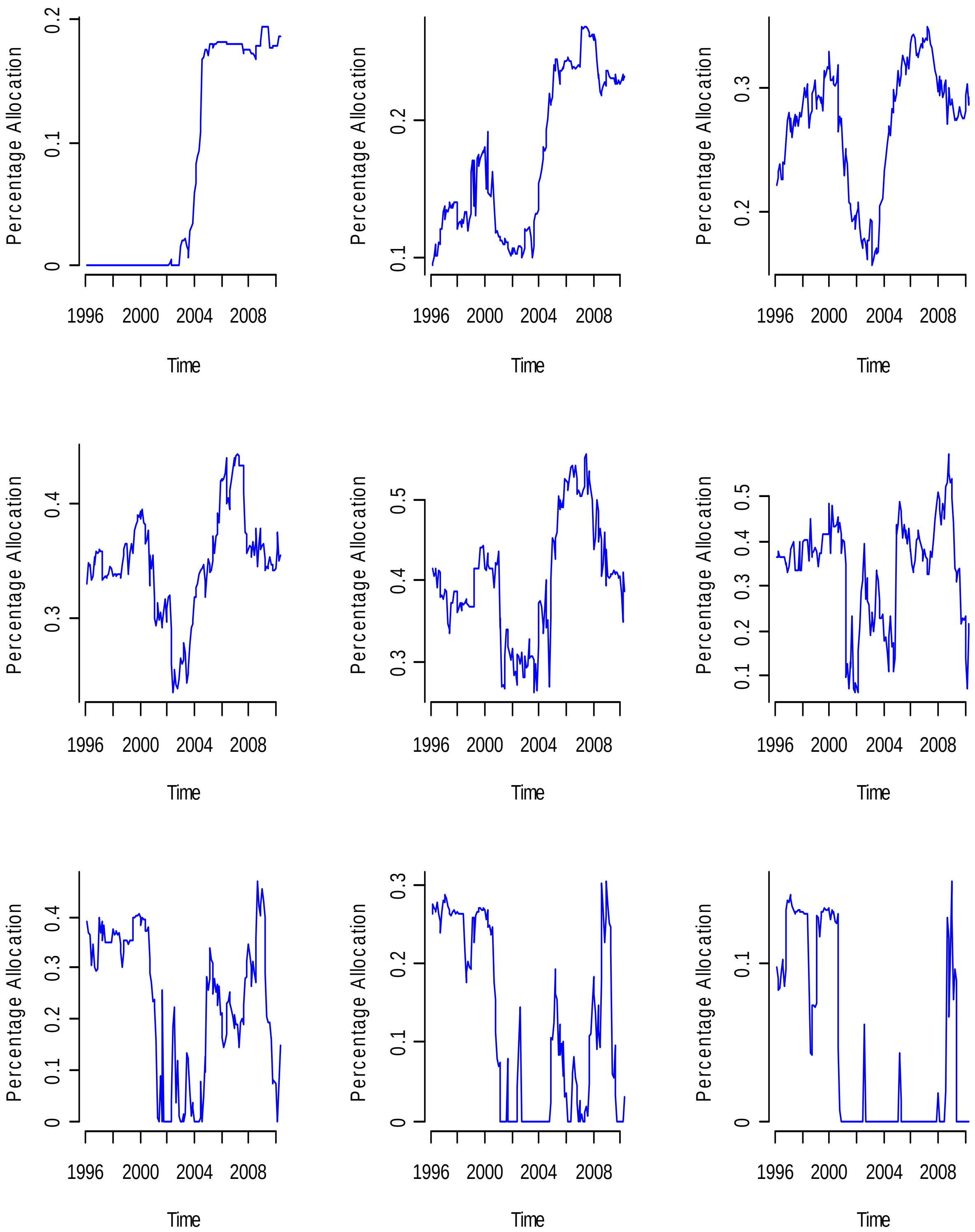


Figure 6: Time-Varying Infrastructure Allocations (α = 0.99)

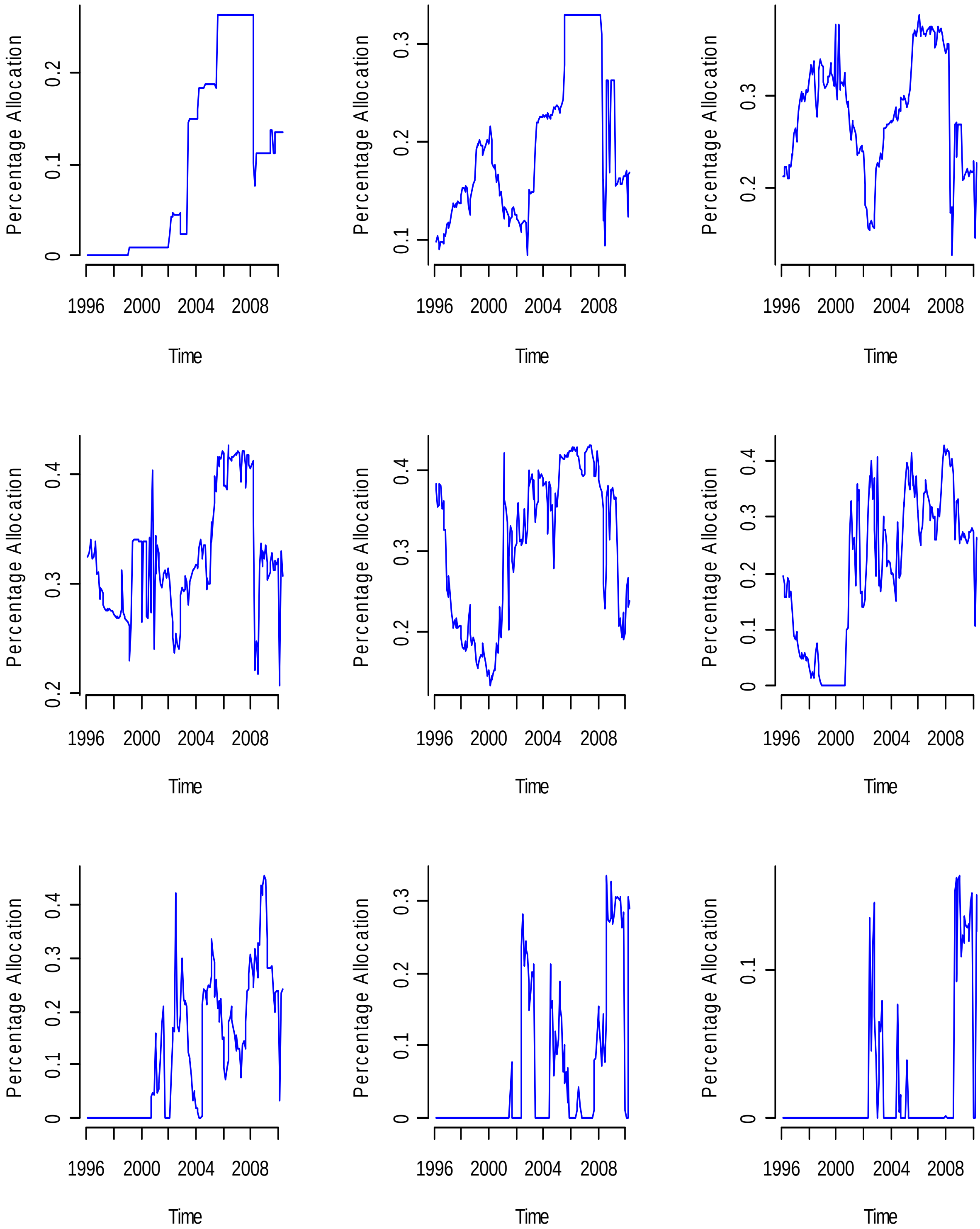


Table 10: Average Conditional Drawdowns of Portfolio Returns with and without Infrastructure April 1996 - July 2010

alpha	MinCDaR	Portfolio 2	Portfolio 3	Portfolio 4	Portfolio 5	Portfolio 6	Portfolio 7	Portfolio 8	Portfolio 9	Portfolio 10
0.00	0.11%	0.18%	0.31%	0.47%	0.65%	0.91%	1.28%	1.75%	2.43%	4.89%
	0.11%	0.10%	0.17%	0.26%	0.44%	0.74%	1.17%	1.68%	2.40%	4.89%
0.80	0.44%	0.77%	1.29%	1.85%	2.49%	3.32%	4.44%	5.81%	8.04%	15.97%
	0.44%	0.48%	0.76%	1.12%	1.74%	2.73%	4.03%	5.56%	7.94%	15.97%
0.90	0.60%	0.99%	1.64%	2.36%	3.16%	4.22%	5.63%	7.33%	10.35%	20.59%
	0.60%	0.65%	1.00%	1.44%	2.26%	3.57%	5.26%	7.17%	10.29%	20.59%
0.95	0.70%	1.18%	1.88%	2.68%	3.60%	4.80%	6.44%	8.47%	12.20%	24.00%
	0.70%	0.78%	1.15%	1.66%	2.73%	4.31%	6.25%	8.41%	12.18%	24.00%
0.99	0.86%	1.37%	2.10%	2.96%	3.95%	5.32%	7.22%	9.63%	14.48%	27.75%
	0.86%	1.01%	1.37%	1.98%	3.11%	4.75%	6.91%	9.50%	14.45%	27.75%

Figures denote the averages of the conditional portfolio drawdowns with and without infrastructure. For each alpha, the first row denotes the average conditional portfolio drawdown when the portfolio is constructed without infrastructure. The second row shows portfolio risk with infrastructure for the **identical expected portfolio return.**

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7. Conclusion

The following section provides an overview of the five papers comprising the main body of this dissertation. This sheds a light on the motivation and role of each individual paper within the general structure, explains the infrastructure data and methodology used and presents the main findings of each article. The work closes with some more general remarks and offers an overview of some potential fields of research on infrastructure investment.

7.1 Executive Summary

The Interactions Between Direct and Securitized Infrastructure and its Relationship to Real Estate

The first publication investigates, for the first time, the long-run relationships and short-run dynamics between direct and securitized infrastructure returns, as well as the relationship between infrastructure and real estate returns. These questions are of fundamental importance for potential infrastructure investors in terms of diversification issues and contribute to the understanding of infrastructure as an asset within an (institutional) investment portfolio. Due to their apparently underlying similarities with similar investment vehicles, investors indentify with infrastructure mainly as assets that are related to/ or are a subset of commercial real estate and therefore often replace real estate with infrastructure assets in their portfolios. The paper analyzes the rationality and financial viability of such behavior and investigates the short-run dynamics and long-term interrelations between real estate and infrastructure assets. The direct infrastructure performance index is provided by the Center of Private Equity Research (CEPRES) and covers a unique dataset of 930 individual operating infrastructure projects in the US. The time series analysis is based on a Q2 1990 to Q2 2010 sample with a quarterly frequency and further includes indirect infrastructure, direct and indirect real estate as well as stock returns. The analysis is based on the Engel and Granger and Johansen cointegration tests (long-run relationships), as well as the Granger Causality test (short-run dynamics).The most relevant findings are as follows. The analysis reveals the existence of a long-run relationship between direct and securitized infrastructure which is driven by a common underlying infrastructure business factor. This result implies that investors are not able to achieve long-term portfolio diversification benefits by allocating funds to both direct and securitized infrastructure, since they are substitutable over the long run. Therefore, asset allocation models which are based on correlations and extended to long horizons could imply diversification benefits which are not in fact present. However, in the short run indirect infrastructure is driven by the general stock market and follows the direct infrastructure market - a status (similar in particular to the "pre-Reit era"), which might reflect the current lack of segmentation and focus of listed infrastructure companies. Furthermore, the investigation is not able to find a relationship between direct infrastructure and direct real estate returns, either in the short run or long run - a result which contradicts to the assumption of infrastructure as being a subset of or substitute for real estate.

Infrastructure: A new dimension of real estate? An asset allocation analysis

The emergence and increasing importance of the asset class "infrastructure" requires a reassessment of traditional portfolio strategies. This paper contributes to this debate, and analyses for the first time the behavior of indirect and direct infrastructure assets within a multi-asset portfolio, by specifically taking into account the theoretical and empirical similarities towards the related real estate sector. Due to the maturity of its infrastructure market and the availability of direct and indirect performance data, the analysis focuses on the Australian market. The dataset includes direct and indirect infrastructure, direct real estate as well as stocks and bonds and spans the Q4 1994 to Q1 2009 period on a quarterly observation bias. In order to isolate the effects of the financial crisis, a second sample explicitly excludes the period between Q3 2007 and Q1 2009. The direct infrastructure index is an equally weighted total return index comprising five Australian infrastructure funds and is corrected for smoothing effects. Portfolio allocations are calculated according to the methodology proposed by Estrada (2006). The static algorithm accounts for downside risk, rather than variance - an approach which is more in accordance with the actual behavior of institutional investors.

The first part of this paper is intended to improve the basic understanding of infrastructure as an asset. Basic theoretical terms relating to infrastructure, as well as similarities and basic differences (especially with regard to related assets like real estate) are defined, in order to gain a better understanding and a more accurate classification of the asset. The theoretical discussion, as well as the empirical investigation, yields the conclusion that two distinct asset classes are present, even though infrastructure and real estate have some common characteristics. In particular, the evaluation of correlation figures provides conclusive evidence of the different performance characteristics of infrastructure and real estate. The portfolio allocation model also reveals some interesting results and suggests the theoretical benefit of substantial allocations to direct and indirect infrastructure. Nevertheless, the last section underlines the hypothetical nature of the results. Nonetheless, the work provides an overview of influence factors and barriers to infrastructure investments, such as immature investment market structures, a lack of secondary markets, large lot sizes as well as long transaction periods.

Real Estate: A Victim of Infrastructure? Evidence from Conditional Asset Allocation

Due to their underlying similarities, the inclusion of infrastructure might, in particular, affect the allocation to real estate and consequently, the question arises of whether it is rational from an investors point of view to substitute (at least partially) real estate with infrastructure assets in the portfolio. The analysis specifically accounts for different target allocations, up and down phases of the general investment market and also sheds light on the role of infrastructures in constrained asset portfolios. The analysis is based on US data with a quarterly frequency and spans the horizon Q2 1990 to Q1 2009. In order to obtain robust results, the study applies a broad set of assets including direct and indirect infrastructure, direct and indirect real estate, cash, bonds, small and large cap stocks, private equity and commodities. The optimization technique accounts for downside risk and is based on Bawa and Lindeberg (1977) and also includes correlation measures in accordance with this definition of risk.

The results show that infrastructure is an important asset for portfolio diversification and that theoretical allocations to direct real estate are likely to be overestimated when direct infrastructure is not considered. Although the allocation to direct real estate also suffers in down markets when infrastructure is included, this effect is not as distinctive as in unconditional market states. This is caused mainly by relatively high direct real-estate returns in down markets, which significantly exceed those from direct infrastructure. However, analysis also shows find that direct real estate *and* direct infrastructure constitute attractive investments for downside risk-averse investors, especially during equity market downturns but direct infrastructure is weighted more heavily than direct real estate, as it also provides diversification benefits and exhibits a low level of downside risk when stock markets perform badly. Moreover, compared to direct real estate, direct infrastructure asset weights are very sensitive towards changes in investor-specific target returns. Nevertheless, neither infrastructure nor any other alternative asset is able to replace real estate in institutional investment portfolios as a whole. Although the allocation to direct real estate is below the findings in other asset allocation studies, the importance of direct real estate is evident. Especially in down markets, there is no other asset which delivers such high returns, while providing similar diversification benefits.

How much into Infrastructure? Evidence from Dynamic Asset Allocation

Paper four uses a dynamic optimization process to investigate the role of infrastructure in a multi-asset portfolio context. The dynamic optimization analysis focuses on a rolling, as well as an extending window approach, and also takes into account constrained and unconstrained portfolio observations. The paper considers in detail how the inclusion of infrastructure affects the risk and return characteristics of the portfolio. A further focus is on the effect of the specific investment horizon on infrastructure allocations and the difference between an observation in real as opposed to nominal returns. An additional element of the research concerns the relationship between infrastructure and real estate. The analysis is conducted on a quarterly frequency, deals with US data and ranges from Q2 1990 to Q2 2010. The dataset includes direct infrastructure (CEPRES US infrastructure index), direct real estate, cash, small and large cap stocks, as well as corporate and government bonds of different maturities. The analysis was conducted using a dynamic mean-semivariance and a mean-downside risk measure in accordance with Estrada (2008). The results demonstrate that infrastructure constitutes an important asset for portfolio diversification and is allocated particularly to low and medium-risk portfolios with maximum allocations of 32% and 28%, respectively. With increasing investment horizons, infrastructure is also allocated to portfolios which aim at yielding higher expected returns – a result which stems from stable returns and a low probability of yielding losses. Moreover, infrastructure proves to be a particularly attractive investment for long-term downside risk-averse investors. The analysis does not reveal strong evidence that the inclusion of infrastructure significantly affects the weightings to real estate and it is not able to replace property in the portfolio. Different risk and return characteristics, along with diverging asset allocation patterns, speak in favor of two separate asset classes. Infrastructure exhibits a high positive correlation with large cap stocks, which makes an investment less attractive when a certain proportion of total wealth has already been allocated to large cap stocks. This result is independent of the optimization algorithm. Investors being aware of this fact could explain why there is a lower allocation to infrastructure in institutional investment portfolios than suggested by theoretical models.

Direct Infrastructure Investment and its Role in Drawdown-Efficient Portfolios

The final publication further contributes to the debate on how much infrastructure is "optimal" and applies a series of asset allocation models which reflect the requirements of different types of investors. More precisely, the analysis focuses on unconstrained portfolios, constrained portfolios, the ability of infrastructure to hedge pension liabilities, as well as predefined target rates of return and also sheds a light on the ability of infrastructure to protect the portfolio against systematic equity market downside risk. In order to obtain results which are more robust, a monthly data frequency from Q2 1990 to Q2 2010 has been applied. Besides the CEPRES US infrastructure index (direct infrastructure), the dataset comprises large and small cap stocks, bonds of different maturities as well as cash. The applied risk measure is the Conditional Drawdown at Risk (CDAR) which was introduced by Chekholov et al. (2000, 2003, 2005). In order to account for time varying asset characteristics, we employ a dynamic asset allocation procedure, which estimates efficient asset weights at each point in time. The results show – independent of the particular model - that infrastructure is allocated significantly to low and medium-return portfolios and that infrastructure allocations vary over time. Additionally, infrastructure does not prove to be a good hedge against pension liabilities, but traditional assets such as small caps, large caps and long-term government bonds are preferable. This outcome might be associated with the modeling of pension liability returns, which are strongly related to the returns on long-term bonds. When asset returns are targeted against some predetermined benchmark so as to reflect capital cost, the role of infrastructure in low-risk portfolios is even more accentuated. Due to the inability of cash to achieve higher return targets, infrastructure is weighted more heavily than in the first model. As infrastructure does not correlate with equity returns in down markets, it proves to be a valuable hedge against downside systematic risk and also results in portfolio compositions which exceed those in current investment portfolios

7.2 Final Remarks and Further Research

By using a unique dataset, for the first time, this dissertation enables a detailed analysis of the role of direct infrastructure investments in a portfolio context. The results indicate that infrastructure has the potential to play a crucial role in institutional investment portfolios in the ensuing years, especially for investors with moderate return expectations. Moreover, the unique asset characteristics support the argumentation that infrastructure should be regarded as a separate asset class.

Infrastructure allocations and investment strategies depend largely on investor-specific requirements like the market phase, liquidity, return expectations, risk aversion, investment horizon, target rates of return or the desire to hedge the portfolio against liabilities or equity market downturns. However, infrastructure allocations seem to be clearly advantageous, especially in low-to-medium expected return portfolios. This result is consistent over all applied models and markets and reflects the nature of infrastructure as a conservative asset, which predominantly yields only modest returns, but also limits the volatility and risk exposure of a portfolio. Infrastructure offers substantial diversification benefits with respect to conventional assets like stocks, bonds and real estate and protects a portfolio against extreme downturns in value.

However, although infrastructure in theory offers some attractive investment characteristics, the development and success of the asset class depends largely on various different factors. The market structures are still immature and in-transparent, and lack professional structures and efficient secondary asset markets. Although they are under pressure to privatize infrastructure assets and could have learned their lessons from countries like Australia and Canada, most governments failed to develop a professional framework to effectively structure, implement and control these relevant processes in a standardized manner. However, the demand side of private infrastructure investment opportunities is also still in its infancy. Most investment professionals, in the form of institutional investors and investment analysts, for example, are still inexperienced with regard to infrastructure investments and are thus unable to adequately value these investments. Instead of taking into account its attractive and unique characteristics and distinct role within the portfolio, infrastructure investments are still often managed and valued from a related-sector perspective (like real estate). A lack of data and of benchmarks and thus of independent (academic) research, significantly contributes to the problems. Along with a maturing infrastructure market, new data could further contribute to research by considering different markets and specific infrastructure sub-sectors in financial models. A comprehensive dataset of single-asset deals could further facilitate a sector specific analysis, which sheds some light on this heterogeneous asset class. Since many investors adjust their strategy along with their liabilities, one could further investigate this issue and analyze the specific role of infrastructure over long term horizons. A further research stream should focus associated on the relationship between indirect and direct infrastructure and its long-term diversification benefits. Additionally, infrastructure assets are often regarded as hedging inflation. This claim is unlikely to hold for the asset class in general, being largely dependent on the specific asset design. Therefore, this might be an useful topic for future research, especially considering the question which type of infrastructure project indeed provide a hedge against inflation.