Portfolio of Infrastructure Investments: An analysis of European Infrastructure

Athina Panayiotou
QASER Laboratory
University College London
London, WC1E6BT
athena.panayiotou.12@ucl.ac.uk
Tel. 0044 20 76791557

Francesca Medda
QASER Laboratory
University College London
London, WC1E6BT
London
f.medda@ucl.ac.uk
Tel. 0044 20 76791557

Abstract:

Infrastructure is receiving much attention in recent years. Investing in infrastructure is particularly effective and suggested for institutional investors such as pension funds due to the characteristics of infrastructure assets. However, robust analytical and empirical analyses that support these investments are limited due mainly to scant empirical data. In this work by collecting relevant data sets on infrastructures, we address two objectives. First, we examine the significance of listed infrastructure sectors and sub-sectors by assessing the investment characteristics and performance of different infrastructure indexes in Europe. The aim here is to determine how an effective and successful infrastructure portfolio should be constructed. Our second objective is to evaluate the strategy of infrastructure investors, in other words, if the investor should invest in a portfolio containing different infrastructure sectors or

whether it is still possible to obtain diversification benefits by investing in only a single infrastructure sector.

1. Introduction

Since the early 2000s, firstly due to the availability of 'cheap' debt and then due to the need for an alternative asset class after the financial crisis, private investors have steadily become interested in infrastructure[1] investments in Europe, Asia and the United States (Inderst 2009). This asset class has garnered particular attention recently not only because of the distinctive investment characteristics of the sector but also in response to the recent global financial crisis, which have compelled governments to turn to infrastructure investments for economic recovery (RREEF 2011). However, for instance in Europe despite the willingness of many governments to invest in infrastructure as a means of boosting their economies, budgetary constraints imposed by the financial recession on European governments have restrained their enthusiasms towards this investment class (Gomez and Vassalo 2014).

Infrastructure investments are not only on the agenda of governments but also private investors are examining these investments with great interest. A study made by Preqin (2013) shows that institutional investors, such as pension funds, will continue to allocate globally, significant amounts of capital to infrastructure assets, thereby gaining exposure to European infrastructure assets in particular. Their analysis demonstrates that starting from 2010, European fundraising levels have doubled year-on-year (Preqin 2013) and that 42% of infrastructure funds are allocated in European infrastructure

[1] Infrastructure is often split into two categories: economic and social infrastructure. Economic infrastructure consists of transport services (rail, ports, roads and airports) and other services, such as utilities, energy and telecommunications (Russ et al. 2010), whereas social infrastructure refers to public assets such as hospitals, schools and prisons.

(Preqin 2014). We can observe that the annual European infrastructure deal flow has risen significantly due to secure political, regulatory and economic conditions, and to the existence of numerous investible assets with uncorrelated and stable returns (Preqin 2013).

Despite the increased demand for European assets, there are limited specific researches in this area, mainly due to scant empirical data. Most of the existing study concentrates on global infrastructure (RREEF Research 2009) and on the Australian infrastructure market, as it is the most mature market (e.g., Finkenzeller et al. 2010; Peng and Newell 2007; Newell et al. 2011). To date, the research dedicated to the European infrastructure class (Oyedele 2013; RREEF Research 2010; Newell and Peng 2007) often examines listed infrastructure as a whole with limited scrutiny on the economic characteristics of this investment class rather than gives thoroughgoing attention to specific infrastructure sectors. Moreover, most of the aforementioned research assumes that the infrastructure sectors have the same distinctive and attractive investment characteristics; nonetheless there is no specific empirical evidence to support such assertion. Infrastructure is a new vast asset class consisting of many different sectors, each with its own features and historical performance. As Hall et al. (2014) argue one of the major challenges in understanding the long-term performance of infrastructure is the complexity of the sector. Addressing the present knowledge gap will therefore be our objective in this work.

Against this background, the objectives of this analysis are twofold. Our first research objective is to understand the investment profile of each infrastructure sector and sub-sector. Our second and most important aim is to analyze the significance of this sectorial and sub-sectorial differentiation in investor's investments. To address the first objective, we show how investment characteristics of many different European infrastructure sectors and sub-sectors compare with those of more traditional assets in order to conduct a robust analytical examination of the investment profile of different infrastructure sectors and sub-sectors. In order to address our second aim we examine whether it is beneficial for an investor to build a portfolio of different infrastructure sectors or if it is still possible to obtain diversification benefits by investing in one sector only. We assert that proving the optimality of portfolios, even when investments are focused in a single sector, is important, as in that way the manager of the portfolio will still be able to diversify and yet will also develop a deeper understanding of the behavior of the sector.

The paper is structured in the following way: Section 2 reviews the available literature. Section 3 describes the data and methodology used in the present research. A discussion of our analysis results is provided in Section 4 and 5, with conclusions drawn in Section 6.

2. Literature Review

One key characteristic of infrastructure assets which distinguishes them from all other traditional assets is that they usually operate as a natural monopoly. Under a natural monopoly model, efficient cost optimisation occurs if there is only one firm responsible for the entire output of an industry (Mackay-Fisher 2012). As such, infrastructure assets usually have one or more of the following characteristics: high barriers to entry, economies of scale, inelastic demand, and long-duration (Inderst 2009). These characteristics convey many attractive investment features to the infrastructure assets, including:

- secure stable cash flows,
- low correlation to other assets,
- inflation hedging properties, and
- low correlation with macroeconomic conditions.

As a result of the strong interest in infrastructure, there is a range of infrastructure projects, listed infrastructure funds, companies, and unlisted infrastructure funds from which to examine the investment characteristics of this asset class (Oyedele 2013; Peng and Newell 2007). As mentioned above, research is mainly focused on the performance of the global and Australian infrastructure market.

According to a performance survey of 100 European Pension Schemes, the expectation of returns for infrastructure assets over a period of 10 years are annualised at 9.5%, lower than private equity but higher than stocks, bonds and cash (Inderst 2009). The asset-liability model of Morgan Stanley Investment Management (2007) compared five different asset classes and found that infrastructure falls behind bonds in terms of volatility and behind private equity in terms of returns. Rickards (2008) also compared the performance of infrastructure assets to equities, emerging markets and cash over a period of 12 years. His results indicated that, on a risk-adjusted return basis, infrastructure outperforms other assets, and he further confirmed that infrastructure's inherent characteristics yield better returns and lower volatility.

The first academic study on the performance of infrastructure funds was carried out by Peng and Newell (2007) using both listed and unlisted infrastructure funds in Australia.

Australia has a relevant and available data on infrastructure due to its significant experience with unlisted infrastructure funds. The authors compared the performance of 19 unlisted infrastructure funds, 16 listed infrastructure funds and 16 listed infrastructure companies. They evaluated the performance of funds using returns obtained by UBS for listed infrastructure funds and listed infrastructure companies; and for the unlisted infrastructure funds they used an equally weighted index of 5 out 19 major Australian unlisted funds. For the period between Q3. 1995–Q2. 2006, Peng and Newell found average annual returns to be 22.4% for listed infrastructure and 14.1% for unlisted infrastructure. Higher returns of listed infrastructure came, however, at the expense of much higher volatility (16.03%) than all other assets. Whereas unlisted infrastructure fund performance achieved higher average annual returns from Listed Property Trusts (LPTs), Real Estate Investment Trusts (REITs), stocks, direct property, and bonds. The annual volatility of unlisted infrastructure funds was 5.83%, higher than direct property and bonds, but with lower volatility than (LPTs) and stocks.

Another interesting study was conducted in 2010 by Colonial First State Global Asset Management (CFS-GAM) which confirmed that listed infrastructure shows higher returns for a 10-year period up to 2006 than unlisted infrastructure, direct property and bonds, but also shows higher volatility. However, the results were not consistent when compared to a shorter 3 or 5-year period (Beeferman 2008). A more recent study carried out by the CFS (2010), using their own index of 5 unlisted infrastructure funds in Australia from 2000-2010, demonstrates that volatility and good risk-adjusted returns compare favorably to other assets.

At this point, we need to notice that one important characteristic of infrastructure assets is that they have low dependence on macroeconomic conditions, thus guaranteeing the resilience of infrastructure returns during periods of low economic activity. Beeferman (2008,) as in the study of Peng and Newell (2007), when calculating the Sharp ratio, has shown that unlisted infrastructure had the highest Sharp ratio of all other asset classes, with the exception of direct property. Newell et al. (2011) in order to account for the effects of the financial crisis, focus on the same unlisted infrastructure funds as CFS study (2010) and Listed infrastructure but extended the dates over a 14-year period, from Q3. 1995 to Q2. 2009. Compared to previous studies, all annual returns were lower for all assets except unlisted infrastructure, which remained unchanged at 14.1% with a volatility of 6.27%. Listed infrastructure was the third best performing asset after unlisted infrastructure and direct property with an annual return of 16.7% and volatility 24.6%. During the financial crisis, specifically during the period between Q2. 2007 and Q2. 2009, all returns from asset classes were negative except for unlisted infrastructure funds and bonds. Importantly, unlisted infrastructure funds showed the highest Sharp ratio of 0.32 while bonds had a Sharp ratio of 0.15. The study of CFS (2010) also confirms this conclusion. Their index of 5 Australian unlisted funds was less affected by the financial crisis, thereby verifying that unlisted infrastructure performance is robust during an economic downturn.

Another pertinent observation is related to the correlation with other assets because diversification can be achieved by investing in assets with a low correlation of returns. The analysis of correlation of returns is heavily constrained by the lack of available data so most studies use listed infrastructure indices. For instance, a study made by Deutsche Bank asset management unit RREEF (2007) evaluates the performance and correlations of global returns for 10 years among alternative assets and traditional assets analyzing UBS listed infrastructure. The authors define alternative assets as illiquid assets that have a limited investment history, they are uncommon to use in portfolios and they require specialized manager knowledge. The results show that listed infrastructure has a negative correlation with bonds but it moves with general stock market volatility which shows a moderate correlation between listed infrastructure funds and stocks. It is interesting that listed infrastructure shows higher correlation with other assets compared to unlisted infrastructure. For instance, Peng and Newell (2007) estimate that listed infrastructure had a correlation of 0.21 and 0.38 with equities and bonds respectively, but a correlation of 0.03 with private equity; whereas, unlisted infrastructure has lower correlations with equities and bonds of 0.06 and 0.17 respectively, but a higher correlation of 0.26 with direct property.

The implication of these studies is that infrastructure assets can be used as a shock absorber within a portfolio. Since infrastructure moves independently, it can offer moderate to high returns at times when other assets' returns are decreasing. According to Rickards (2008), private investors would benefit from investing in infrastructure. Given these low correlation results, some analysts have attempted to identify whether including infrastructure assets in a portfolio will lead to a shift in the efficient frontier, giving better risk-return combinations of investment portfolios. In a CSAM (2010) study, results indeed indicate that adding 5% of listed infrastructure to an institutional pension portfolio of 43% equities, 24% fixed income, and 33% alternatives, would keep the return of the portfolio the same 8.8% but it reduces the target risk from 11.7% to 11.4%. Similarly, CFS (2010) shows that adding 5% of unlisted infrastructure increases the portfolio return by only 0.1% but decreasess the risk of the portfolio by 0.5%.

Idzorek and Armstrong (2009) carry out several historical portfolio Markowitz optimizations in addition to a forward-looking optimization, by using several CAPM assumptions and they demonstrate that optimal allocation for infrastructure is between 0 and 6%. Finkezeller et al. (2010) by using historical returns and implementing a mean-semi variance approach, calculate the optimal infrastructure allocation at different risk levels. They conclude that low risk investors should include unlisted infrastructure in their portfolios whereas high risk investors should include listed infrastructure.

However, as for now research on the European infrastructure market is limited. For instance, in 2010 the RREEF study on the performance of European listed infrastructure assets. The indexes used are UBS Developed Infrastructure & Utilities Europe, UBS Developed Utilities infrastructure, UBS Developed Infrastructure Europe, and Dow Jones and Brookfield Infrastructure Europe. The study shows that UBS Infrastructure-only index has the highest return among other asset classes such as stocks, bonds, real estate and private equity. Oyedele et al. (2013) also examine the performance of listed infrastructure over a 10-year period (2001-2010) as well as the significance of listed infrastructure in a mixed-asset portfolio. The work of Oyedele et al. is one of the few studies that also presents some sub-sector analysis performance, as they test the performance of UBS indexes on toll roads, airports, ports, power generation, integrated utilities and integrated regulated utilities. Results of the research indicates that European infrastructure showed an attractive annualized return and an acceptable volatility; and it outperformed more traditional assets such as European stocks and European REITs but performed poorly compared to European bonds. Oyedele et al. (2013) examines the performance of infrastructure during the financial crisis period and in so doing he considers differentiation component among the various infrastructure sub-sectors, such as ports. The results show that infrastructure had negative annualized returns and high volatility but the infrastructure sub-sector has an overall better performance of the infrastructure. The portfolio results demonstrate that infrastructure plays a significant role in the optimality of mixed asset portfolios, the incurred benefits however, are more due to enhancing returns rather than reducing risks.

We can surmise from the literature review that a gap in the literature with regard to the behavior of the different infrastructure sectors and sub-sectors needs to be addressed. In the next sections we will address our two objectives. In so doing, to address our first objective, we assess the investment characteristics and performance of infrastructure indexes in Europe from 2003-2013 for the sector analysis and from 2004-2013 for the sub-sector analysis. Additionally, to address our second objective we examine whether the private sector is better off by investing in an infrastructure portfolio containing a mix of infrastructure sectors or if it still obtains diversification benefits by investing in one specific sector.

3. Data and Research Methodology

In order to address our two objectives, we have collected data from Thomson Reuters Database. The data include historical time series of monthly returns of European indices over a time span of 11 years (2003-2013) for the infrastructure sector analysis, and weekly returns of European indices over a 10-year time span for the sub-sector analysis (2004-2013). For the sector analysis the assets included are Thomson Reuters European indices in Energy, Utilities, Transport, Telecommunications, Government Bonds, Real Estate, and Stocks. For the sub-sector analysis we use the following listed European sub-sectors indices: Thomson Reuters Europe Ports Index, UBS Europe Toll Roads Index, UBS Europe Airport Index, Europe Total Market Electricity Index, Thomson Reuters Europe Fossil Fuels Energy Index, MSCI European Power and Electricity Index, Thomson Reuters Renewable Energy Index, and Thomson Reuters European Natural Gas Index. Risk free monthly returns from the same period are collected from the Kenneth R. French Data Library in order to calculate the Sharp Index of each asset. The risk free assets used are Treasury monthly T-bills.

The analysis of the European infrastructure asset performance represents our first objective and we develop this analysis on the basis of three aspects. Firstly, we calculate the annualized return, annualized volatility and Sharp Index of each index for the whole period (for the sector analysis from Q1. 2003 to Q4. 2013 and for the sub-sector analysis from Q1. 2004 to Q4. 2014). These three measures are used to compare the performance among the different assets over the long-term.

The Sharp Index is calculated by the following formula:

$$\text{Sharp Index} = \frac{Return_i - Return_{R_f}}{SD_I}$$

where:

$Return_i$ = Return of asset *i*.

$Return_{R_f}$ = The return of a risk free asset (in this research Treasury monthly T-bills are used).

Secondly, diversification benefits among infrastructure assets as well as with other traditional assets (e.g., Stocks, Real Estate and Government Bonds) are evaluated based on the assets' returns matrix correlation. Lastly, since the period examined is interesting as it covers the period of the recent financial crisis, as a last performance test we contract our dataset from Q4. 2007 to Q2. 2009 to cover only the years of the financial crisis. The annualised return, annualised volatility and Sharp Index are re-calculated for this 3-year period in order to examine the robustness of listed infrastructure sectors and sub-sectors.

For the second objective of this paper, i.e. to confirm the best way to construct a portfolio that invests in infrastructure, a portfolio historical analysis is performed using the standard Markowitz (1952,1959) mean-variance portfolio optimisation technique as in Oyedele (2013).

The return of the portfolio is calculated as follows:

- $Return_{portfolio} = \sum_{1}^{n} w_i * r_i$

where:

w_i= Weight of ith/individual security or asset in portfolio

r_i = Return of individual security

And the variance of the portfolio is calculated by:

- $Variance_{portfolio} = \sum_{i}^{n} w_i^2 * SD_{ij} + 2\sum_{j=1}^{n}\sum_{i=1}^{n} w_i w_j r_{ij} SD_i SD_j$ for i≠j

Where:

- $Variance_{portfolio} = var_p$
- $SD_P = \sqrt{var_p}$
- $r_{ij} = Correlation\ coefficient\ between\ the\ ith\ and\ jth\ variables$
- SD_{ij} = *Covariance of the ith and jth variables*
- SD_i = *Standard deviation of the ith variable*

After the recent financial crisis, tail-risk analysis has proved to be of vital test to evaluate investors' portfolio risk. For this reason we also estimate the Mean-Conditional Value at Risk (M-CVaR) optimization (Bianchi et al., 2014). The results of the M-(CVaR) optimization are then compared with the Mean-Variance framework to check their robustness. One of the arguments against Markowitz (1952,1959) approach is that the Mean-Variance portfolio measures the risk of the portfolio as the standard deviation; however, this is only valid when the returns are normally distributed. For this reason, we also undertake a second portfolio optimization technique, the M-CVaR portfolio, which uses simulations that do not necessary assume that the distribution of the data is normal. The M-CVaR calculates the highest returns you can obtain for a given level of CVaR at the 95% confidence level.

The $VaR_{\alpha}(x)$ for portfolio x, means that with a (1- α) probability, the returns will not fall below this level. The conditional value at risk, which is also known as expected shortfall, is the expected loss of the portfolio returns above the $VaR_{\alpha}(x)$. Following Rockafellar and Uryaser (2000,2002):

The conditional value-at-risk for a portfolio $x \in X$, is defined as

- $CVaR_{\alpha}(x) = \frac{1}{1-\alpha} \int_{f(x,y)\geq VaR_{\alpha}(x)} f(x,y)p(y)dy,$

where

- α is the probability level such that $0 < \alpha < 1$. In this study the probability level is 0.95.
- f(x,y) is the loss function for a portfolio of x and asset return y.
- p(y) is the probability density function for asset return y.

VaR_{α} is the value-at-risk of portfolio x at probability level α.

The value-at-risk is defined as

- $VaR_{\alpha}(x) = \min\{\gamma : \Pr[f(x,Y) \leq \gamma] \geq \alpha\}$.

The results of the two optimizations are compared in two ways:

- We convert the risk proxies to be able to compare the two portfolios. Using the CVaR portfolio weights we calculate the mean-variance risk of the 10 M-CVaR efficient frontier portfolios. This will enable us to compare the efficient frontiers of both optimisations and observe any differences.
- By using area plots we visualise the weights of both the mean-variance and the M-CVaR and we compare the weights of the chosen assets.

In order to examine how it is most beneficial to construct a portfolio with infrastructure investments, we carry out two different assessments. We first evaluate the significance of European infrastructure in traditional portfolios and then verify whether an investor can still obtain diversification benefits by focusing on a single sector only. We consider two different sectors: Transport, which we identify as a stable sector, and Energy which due to the present innovative but disruptive energy technology we describe as relatively unstable sector, and thus it has less attractive financial performance. We use the GAMS modelling tool to conduct the Mean-Variance optimisations while, the Conditional Value-at-Risk Portfolio Optimisation is estimated in Matlab.

We set out to optimise the following portfolios:

- Portfolio 1 includes only European traditional assets (Stocks, Real Estate and Government Bonds).
- Portfolio 2 includes the same assets as portfolio 1 plus the addition of all infrastructure sectors.

- Portfolio 3 specialises only in transport sub-sector assets (Airports, Ports and Toll Roads) within a traditional portfolio.
- Portfolio 4 specialises only in the energy sub-sector assets (Natural Gas, Electricity, Fossil Fuels, and Renewable Energy) within a traditional portfolio

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4. Results: performance analysis of different infrastructure sectors and sub-sectors

In this section we address our objectives:

- Performance analysis of different infrastructure sectors and sub-sectors

For the first objective, performance analysis of different infrastructure sectors and sub-sectors, the analysis is divided in two: the sectorial analysis which involves the examination of the performance of four different infrastructure sectors (Energy, Telecommunications, Utilities, and Transport) among traditional assets (Stocks, Real Estate and Government Bonds), and the second part of the analysis which repeats the same performance tests but concentrates specifically on the components of two infrastructure sectors (Energy and Transport). In the second analysis we examine the performance of Natural Gas, Electricity, Fossil Fuels, and Renewable Energy when focussing only on the Energy sector, and the performance of Airports, Ports and Toll Roads when focusing only on the Transport sector. In the sub-sector studies we compare infrastructure assets with the same traditional assets as in the sector analysis (Stocks, Real Estate and Government Bonds). For both analyses the results of the whole dataset are presented first, in order to examine and compare the long-term historic behavior of the assets. We then examine the contracted dataset in order to verify the robustness of the assets during a financial crisis. Lastly, we scrutinize the diversification benefits among the different assets by calculating the inter-correlation matrix for each analysis.

4 .1 *European Infrastructure sector performance analysis*

Table 1 shows the performance of European assets for the period 2003-2013. The four listed infrastructure sectors show significant variation in their performance, proving that infrastructure should not be treated as a singular asset, and that close attention should be paid to the behavior and historical performance of infrastructure's individual sectors.

As can be seen in Table 1, Transport shows a strong performance over the whole sample period, with a return of 9.35% and volatility at 23.81%. It is the best performing infrastructure asset, with a Sharp Index of 0.334. This is not surprising, as European transport is a very stable sector. Energy instead shows the worst performance of all infrastructure assets, with an annual return of 4.76% and annual volatility of 21.86% resulting in a Sharp Index of 0.153. When comparing the performance of all infrastructure assets with other traditional assets we can conclude that all infrastructure-listed sectors (Energy, Telecommunications, Utilities, and Transport) perform better than Stocks, as illustrated by a higher Sharp Index and they are also less volatile than Real Estate assets. However, Government Bonds show a higher Sharp Index than all of the infrastructure assets.

Table 1. Historical performance analysis of European Infrastructure sectors for period Q1. 2003–Q4. 2013.

European Listed Asset	Annualised Return	Annualised Volatility	Sharp Index	Rank

Energy	4.76%	21.86%	0.153	6
Telecoms	5.24%	19.21%	0.199	5
Utilities	5.96%	20.74%	0.220	3
Transport	9.35%	23.81%	0.334	2
Stocks	2.55%	18.19%	0.063	7
Real Estate	6.56%	24.47%	0.210	4
Government Bonds	5.46%	10.33%	0.392	1

4.2 *European Infrastructure sector performance during the financial crisis*

As mentioned above, our time period is particularly interesting in that it captures the effects of the recent financial crisis. To allow us to isolate the effect of the financial crisis, and to compare the robustness of listed infrastructure sectors in recessions, we contract our dataset to the crisis period (Q4. 2007–Q2. 2009).

The results of the annualised return, annualised volatility and Sharp Index for the period of the crisis are presented in Table 2. From our results we can conclude that all assets, except Government Bonds, were severely affected by the crisis. However, all listed infrastructure sectors were affected less negatively than Stocks and Real Estate, as all infrastructure assets have a higher Sharp Index than Stocks and Real Estate.

Table 2. European Infrastructure sector performance analysis during the financial crisis Q4. 2007–Q2. 2009

European Listed Asset	Annualised Return	Volatility	Sharp Index	Rank
Energy	-25.4%	30.4%	- 0.856	3
Telecoms	-30.0%	24.6%	-1.24	5
Utilities	-30.3%	31.2%	-0.992	4
Transport	-28.2%	35.1%	-0.822	2
Stocks	-41.3%	30.6%	-1.37	6
Real Estate	-53.9%	37.8%	-1.44	7
Government Bonds	4.22%	14.4%	0.247	1

4.3 *Diversification Benefits among assets*

According to Hall et al. (2014), there is little tradition of thinking cross-sectorally about infrastructure system performance, and this prevents us from understanding the long-term performance of infrastructure. Nevertheless, by calculating the correlation among the monthly returns of all assets, we are able to evaluate if there are any diversification benefits among the different listed infrastructure sectors and also between the different infra-sectors and other traditional assets.

The results of the cross asset correlation matrix presented in Table 3 indicate that infrastructure sectors are highly correlated. An explanation of this is given by Hall et al. (2014, p.11), who assert that demand for infrastructure is highly correlated due to the "final demand associated with population and economic growth and because of intermediated demands among infrastructure sectors." For example, a change in demand for electric vehicles would imply a change in demand for the energy sector. This high correlation among the different listed infrastructure sectors proves that there is no benefit gained from constructing a portfolio that invests only in different listed infrastructure sectors.

All of the listed infrastructure sectors in the table show high correlation with traditional assets as well. The high correlation with Stocks is consistent with the literature, which is not surprising, because in the present study we use indices based on publicly-traded infrastructure companies (Inderst 2009); therefore, in this analysis the low correlation with more traditional assets is not confirmed.

Table 3. Cross asset correlation matrix for monthly returns Q1. 2003–Q4. 2013

	Energy	*Telecoms*	*Utilities*	*Transport*	*Stocks*	*Real Estate*	*Government Bonds*
Energy	1						
Telecoms	0.693	1					
Utilities	0.776	0.824	1				
Transport	0.720	0.772	0.845	1			
Stocks	0.727	0.558	0.664	0.610	1		
Real Estate	0.637	0.683	0.792	0.760	0.641	1	
Government Bonds	0.601	0.709	0.707	0.665	0.206	0.644	1

4.4 *Robustness Analysis*

To avoid bias, a second index was selected for all traditional assets (Stocks, Real Estate and Government Bonds) as a control in order to check if the obtained results are index-specific. Table 4 shows the performance of the control indexes over the entire dataset.

Table 4. Control index historical performance analysis for Q1. 2003–Q4. 2013

European Listed Asset	**Annualised Return**	**Volatility**	**Sharp Index**	**Rank**
Stocks	3.05%	14.26%	0.115	7
Real Estate	6.04%	23.46%	0.197	4
Government Bonds	2.65%	7.28%	0.170	5

Nearly all of our conclusions are again confirmed in the robustness analysis. All infrastructure sectors perform better than Stocks, and all infrastructure sectors, except Transport are less volatile than Real Estate. In addition, all infrastructure sectors except Energy have a higher Sharp Index than Real Estate. Government Bonds are still the less volatile asset, however the control index that was used for Government Bonds shows a much lower return. Thus, in the robustness analysis, Government Bonds are not the best performing asset; they are outperformed by all infrastructure assets apart from Energy.

Table 5. Control index cross asset correlation matrix for monthly returns Q1. 2003–Q4. 2013

	Energy	*Telecoms*	*Utilities*	*Transport*	*Stocks*	*Real Estate*	*Government Bonds*
Energy	1						
Telecoms	0.693	1					
Utilities	0.776	0.824	1				
Transport	0.720	0.772	0.845	1			
Stocks	0.713	0.627	0.705	0.668	1		
Real Estate	0.663	0.699	0.809	0.776	0.684	1	
Government Bonds	0.063	0.198	0.160	0.180	0.103	0.059	1

In the robustness analysis the cross asset correlation matrix is calculated and results are given in Table 5. Notably, we can confirm that infrastructure assets are highly correlated with Stocks and Real Estate, but we also observe low correlation with Government Bonds in the robustness analysis. This finding indicates that there are diversification benefits with infrastructure sectors and Government Bonds in a portfolio.

4.5 *European Infrastructure sub-sector analysis*

We next set out to examine the differences between sub-sector assets. The sub-sectors of two different infrastructure sectors (Energy and Transport) have been chosen for our sub-sector analysis. The two sectors are particularly interesting because they behave very differently. The Energy sector is highly changeable, not only in terms of performance, but also due to an unstable regulatory framework (e.g., EU environmental regulation, national renewable energy incentives, feed-in tariffs) which results in higher political risk; whereas the Transport sector represents a relatively stable sector with a fairly stable regulatory framework.

The results of the long-term performance of the Energy sector are presented in Table 6. In the European Energy's sub-sector performance analysis we notice that Electricity was the best performing asset over the period examined, with a Sharp Index of 0.258. However, Fossil Fuels and Renewable Energy performed the worst of all other sub-sectors, with Sharp Indexes of 0.036 and 0.007, respectively. When we compare them to the traditional assets, we observe that all Energy sub-sectors, apart from Renewable Energy, show lower volatility than Real Estate. But Government Bonds have the lowest volatility of all of the assets.

Table 6. European Infrastructure Energy sub-sector historical performance analysis for Q1. 2004–Q4. 2013.

European Listed Asset	Annualised Return	Annualised Volatility	Sharp Index	Performance Rank
Natural Gas	5.27%	18.03%	0.200	3
Electricity	6.74%	19.72%	0.258	1
Fossil Fuels	2.62%	26.76%	0.036	6

Renewable Energy	1.89%	33.82%	0.007	7
Stocks	3.65%	19.69%	0.101	4
Real Estate	3.90%	27.90%	0.080	5
Government Bonds	4.01%	10.89%	0.215	2

The Transport sub-sector analysis results are presented in Table 7. In the table we can see that Ports, shown by its high Sharp Index of 0.386, is the best performing asset. Airports also shows a good Sharp Index of 0.308. In contrast, the performance of Toll Roads is much worse that Airports and Ports, with a Sharp Index of 0.117. This is expected, as Ports and Airports not only obtain revenue from their transport services but also from other services in and around airports and ports (i.e., restaurants, shops and so forth). In contrast, most Toll Roads accrue all their revenue solely from transport demand. Despite this observation, however, research conducted by Gomez and Vassalo (2014) showed that in all European countries the revenues generated from road charges exceed road expenditures, with enough money remaining to also subsidise other policies.

In comparison with the more traditional assets, we observe that all of Transport's sub-sectors (as with the Energy sector) show lower volatility than Real Estate. Furthermore, in the Transport analysis, Government Bonds show the lowest volatility of all sectors as well.

Table 7. European Infrastructure Transport sub-sector historical performance analysis for Q1. 2004–Q4. 2013

European Listed Asset	Annualised Return	Annualised Volatility	Sharp Index	Performance Rank
Airports	7.90%	20.26%	0.308	2
Ports	11.06%	24.33%	0.386	1
Toll Roads	4.20%	21.73%	0.117	4
Stocks	3.65%	19.69%	0.101	5
Real Estate	3.90%	27.90%	0.080	6
Government Bonds	4.01%	10.89%	0.215	3

4.6 *European Infrastructure sub-sector performance during the financial crisis*

In this section we repeat the analysis of the previous section but with a shorter dataset to capture only the period of the financial crisis. Analysis results are shown in Table 8. The performance of the infrastructure sub-sectors during the years of the financial crisis is consistent with the infrastructure sector results. All of the infrastructure sub-sectors were less negatively affected by the financial crisis than Real Estate and Stocks. We can here point up the robustness of infrastructure investments during a downturn in macroeconomic conditions. However, none of the infrastructure sub-sectors was more robust than Government Bonds, which consistently showed the best performance of all the assets during the crisis, with a positive Sharp Index of 0.22.

Table 8. European Infrastructure sub-sector performance analysis during the financial crisis Q4. 2007–Q2. 2009

European Listed Asset	Sharp Index
Natural Gas	-0.82
Electricity	-0.96

Fossil Fuels	-0.60
Renewable Energy	-0.85
Airports	-0.70
Ports	-1.10
Toll Roads	-1.05
Stocks	-1.09
Real Estate	-1.17
Government Bonds	0.22

4.7 *Diversification Benefits among Sub-sector assets*

As has been emphasised in this study, when setting out to understand the behavior of infrastructure systems, it is crucial to recognize the interdependence among the different infrastructure assets. In this section we assess the diversification benefits of both Transport and Energy sectors in order to evaluate whether correlation benefits exist in single infrastructure sectors, and if so, calculate the benefit in each sector.

The results for the Energy and Transport sector are presented in Tables 9 and 10, respectively. Generally, we observe in both sectors high correlation among all Energy and Transport infrastructure sub-sectors with Stocks and Real Estate. However, for some assets we find low correlation with Government Bonds. These results are also consistent with our sector robustness analysis.

In relation to the correlation among the sub-sectors, however, we observe that there is indeed some low correlation within the Transport and Energy sub-sectors; this finding indicates that an investor can obtain diversification benefits, even when investing only in the Transport or Energy sector.

Table 9. Cross asset correlation matrix for Energy sub-sector monthly returns Q1. 2004–Q4. 2013

	Fossil Fuels	*Renewable Energy*	*Natural Gas*	*Electricity*	*Stocks*	*Real Estate*	*Government Bonds*
Fossil Fuels	1						
Renewable Energy	0.688	1					
Natural Gas	0.559	0.475	1				
Electricity	0.726	0.722	0.523	1			
Stocks	0.797	0.729	0.488	0.825	1		
Real Estate	0.734	0.652	0.485	0.658	0.779	1	
Government Bonds	0.427	0.260	0.335	0.199	0.155	0.461	1

Table 10. Cross asset correlation matrix for Transport sub-sector monthly returns Q1. 2004–Q4. 2013

	Ports	*Airports*	*Toll Roads*	*Stocks*	*Real Estate*	*Government Bonds*
Ports	1					
Airports	0.362	1				
Toll roads	0.390	0.648	1			
Stocks	0.425	0.686	0.873	1		
Real Estate	0.456	0.685	0.710	0.779	1	
Government Bonds	0.294	0.460	0.245	0.209	0.516	1

After having analyzed our first objective, we can confirm that infrastructure is comprised of many different heterogeneous assets, each with its own specific performance. As a consequence, we argue that fund managers should therefore be experts in specific sector and sub-sector elements of an infrastructure investment package in order to deeply comprehend the performance and behavior of their investments.

- **5. Results:** How to construct a portfolio of infrastructure investment

In this section we examine how to design an infrastructure investment portfolio, objective 2; four different portfolios are therefore analyzed:

- Portfolio 1 includes only European traditional assets (Stocks, Real Estate and Government Bonds).
- Portfolio 2 includes the same assets as portfolio 1 plus the addition of all infrastructure sectors.
- Portfolio 3 specialises only in transport sub-sector assets (Airports, Ports and Toll Roads) within a traditional portfolio.
- Portfolio 4 specialises only in the energy sub-sector assets (Natural Gas, Electricity, Fossil Fuels, and Renewable Energy) within a traditional portfolio

The results of the four different portfolio scenarios are presented in the Mean- Variance framework and then compared with the M-CVaR optimisation. In relation to objective 2, what is of interest to us for each scenario in the Mean-Variance Framework is whether we achieve a higher Sharp Index by combining different assets instead of investing only in the best performing asset of each scenario.

5.1 European Portfolio analyses with and without infrastructure

- **Portfolio 1 includes only European traditional assets**

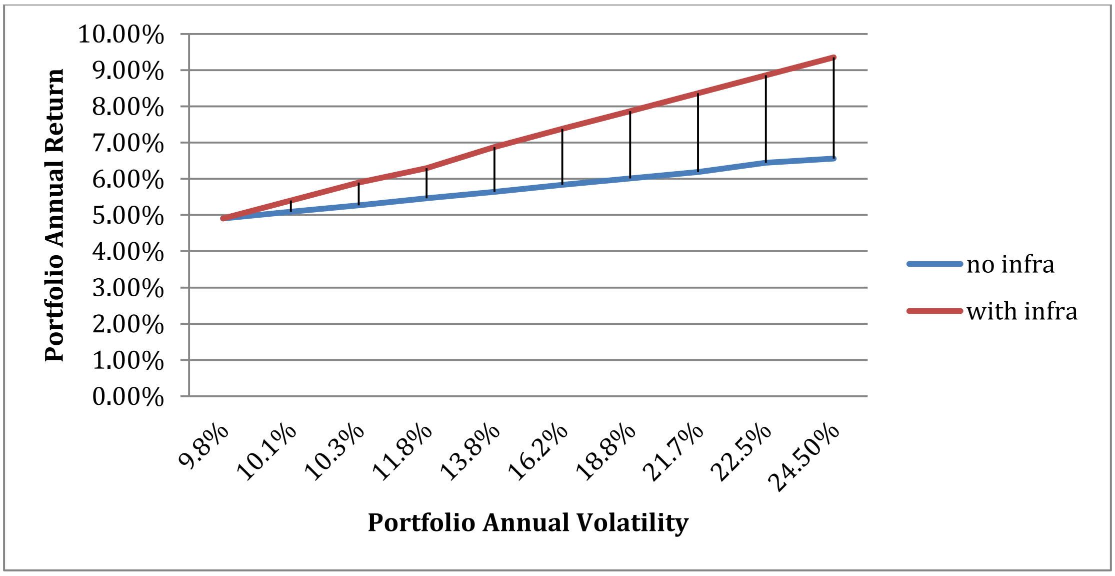
By investing only in Government Bonds gives a Sharp Index of 0.392, while investing only in Real Estate or only in Stocks gives a Sharp Index of 0.210 and 0.063, respectively. By creating a portfolio that combines Stocks, Real Estate and Government Bonds, one cannot achieve a Sharp Index higher than if one were to invest only in Government Bonds; this result proves that in terms of the Sharp Index ratio, it is always more beneficial to invest only in Government Bonds than to combine a portfolio of different traditional assets. However, depending on the risk attitude of an investor, one can combine the three traditional assets to achieve either a lower risk by accepting a lower return or if more risk-loving to accept a higher risk for a higher return (Efficient Portfolio Frontiers can be found in the Appendix).

- **Portfolio 2 includes the same assets as portfolio 1, plus the addition of all listed infrastructure sectors**

Investing in a multi-asset portfolio that combines traditional European assets and listed infrastructure sectors is clearly beneficial. As depicted in Figure 1, by including infrastructure in a traditional European portfolio during the period 2003-2013 provides an outward shift in the efficient frontier. The implication here is that, for the same amount of risk, investors can obtain higher returns.

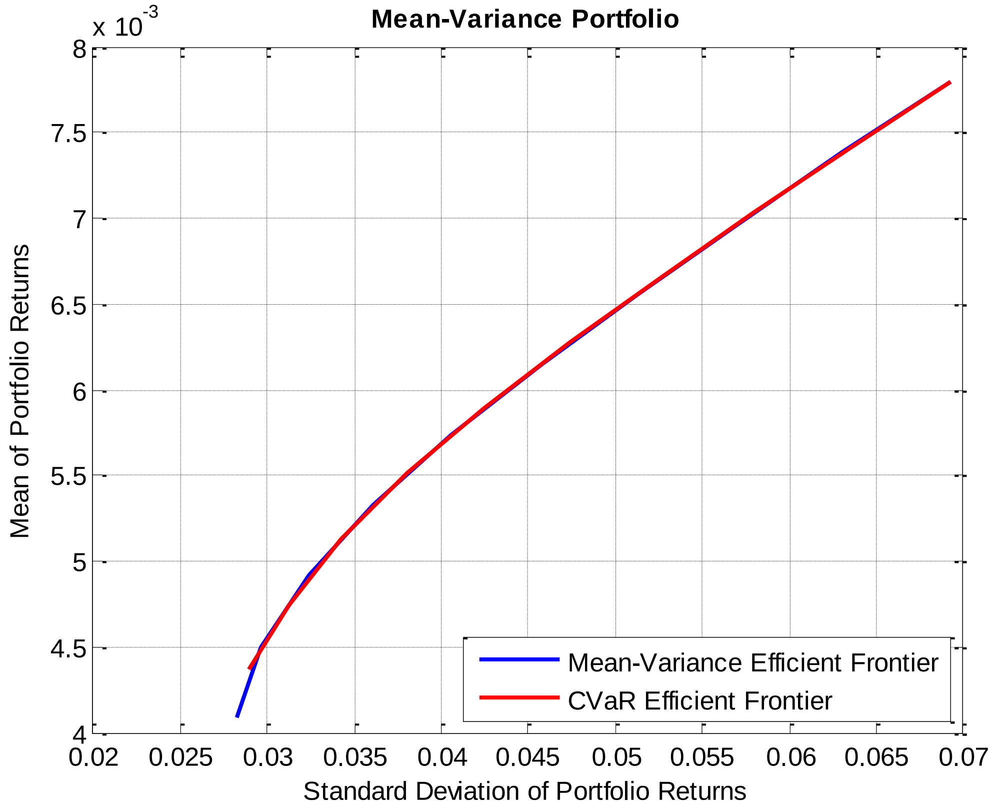
The portfolio that maximises the Sharp Index invests in Transport infrastructure and Government Bonds only, thereby achieving a volatility of 12.1% and a return of 6.29%, resulting in a Sharp Index of (0.402). By including infrastructure in a traditional portfolio, one can obtain a higher Sharp Index than by investing in any asset on its own. It is noteworthy that in none of the efficient frontiers is it optimal to create a portfolio that invests in many infrastructure sectors. This finding verifies our earlier observation that there are no diversification benefits between different listed infrastructure sectors.

Figure 1. Efficient frontiers for Portfolios 1 and 2



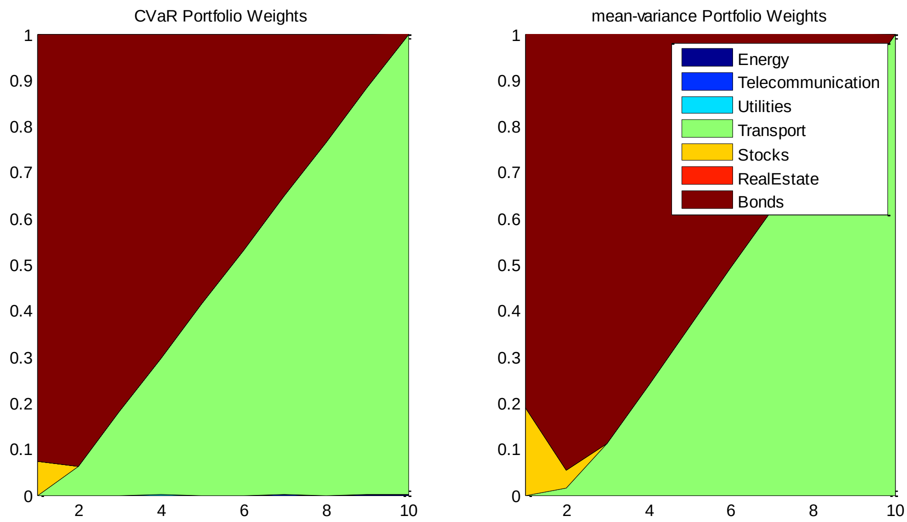
As a sensitivity analysis, we undertook a second optimization technique, the M-CVaR optimization, to check our results (Efficient Portfolio Frontiers can be found in the Appendix). To compare the two optimizations, we calculate the monthly mean-variance risk using the weights of the M-CVaR optimization to convert from one risk to the other. This enables us to convert the efficient frontiers of the M-CVaR optimization to a mean-variance plot. Thus, as illustrated in Figure 2, we draw the Mean-Variance Portfolio Efficient Frontiers for both techniques and compare the differences. From Figure 2, one can observe that our Mean-Variance portfolio results are quite robust as the two frontiers are very similar with some differences at the lower level of the frontiers.

Figure 2. Efficient frontiers for the Mean-Variance and M-CVaR optimization



The second test that we perform is to compare the weights of the assets in the efficient portfolios of the two optimizations. Figure 3 visualizes the weights of both optimizations using area plots. The only difference observed, in the allocation of the assets between the two optimizations, is that the Mean-Variance optimization gives more weight to Stocks than the M-CVaR optimization. However, we can observe that both optimizations choose to invest in the same assets, which are Government Bonds, Transportation and Stocks. Thus, in conclusion we observe that infrastructure is a good addition to a traditional portfolio and that sectors do not mix in the construction of optimal portfolios is confirmed.

Figure 3. Weights Comparison for Portfolios Mean-Variance and M-CVaR optimization



5.2 Sub-sector Portfolio Analysis

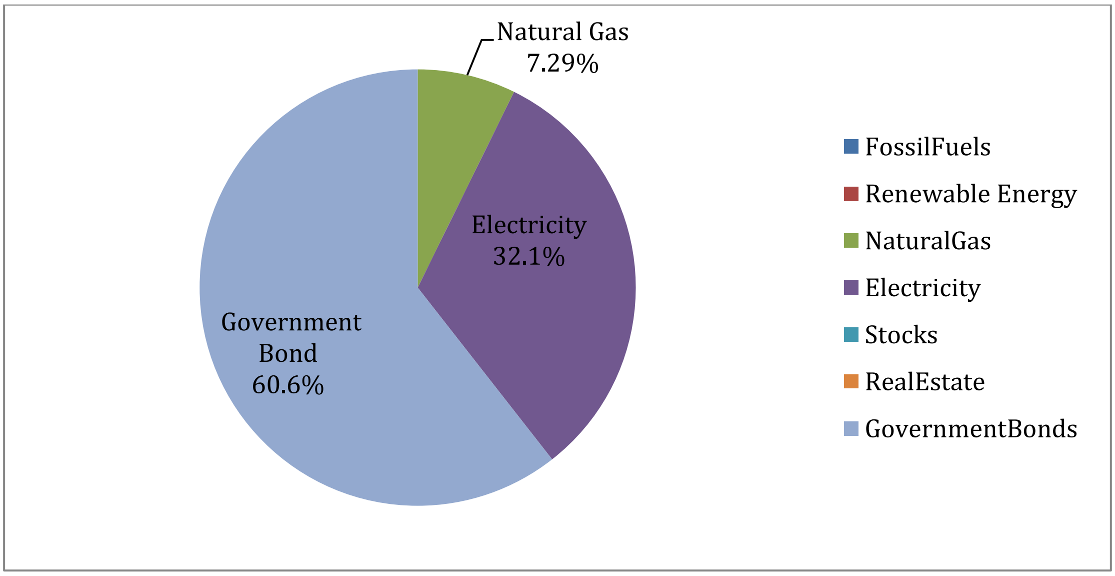
The results of the previous portfolio scenario show that in European infrastructure investment it is not optimal to create a portfolio that invests in various infrastructure sectors. For this reason, in the third and fourth portfolios we evaluate the diversification benefits that exist by investing in a single infrastructure sector alone. As mentioned above, we have chosen to focus on the Energy and Transport sectors because we are interested in detecting the difference between investing only in a stable sector, such as Transport (where political risks are fewer) compared with the relatively new and unstable Energy sector.

- **Portfolio 3 specialises only in energy sub-sector assets (Natural Gas, Electricity, Fossil Fuels, Renewable Energy)**

For the third scenario we construct a portfolio, which includes only Energy sub-sector assets within a traditional portfolio.

As we have seen in the correlation analysis, there are modest diversification benefits in the Energy sector. The portfolio that maximises the Sharp Index, as can be seen by Figure 4, invests 60.6% in Government Bonds, 32.1% in Electricity, and 7.29% in Natural Gas. The highest Sharp Index achieved is 0.311 which is higher than the Sharp Index obtained by investing in any single asset. The optimal portfolio annual return is 5.02% and the annual volatility is 10.8%. We observe that sectors such as Renewable Energy and Fossil Fuels are not included in the optimal portfolio; this observation may be because certain sectors are over-valued by the market. However, there are many possible explanations for the exclusion of Renewable Energy and Fossil Fuels, such as government intervention or the ethics and values of the individual fund.

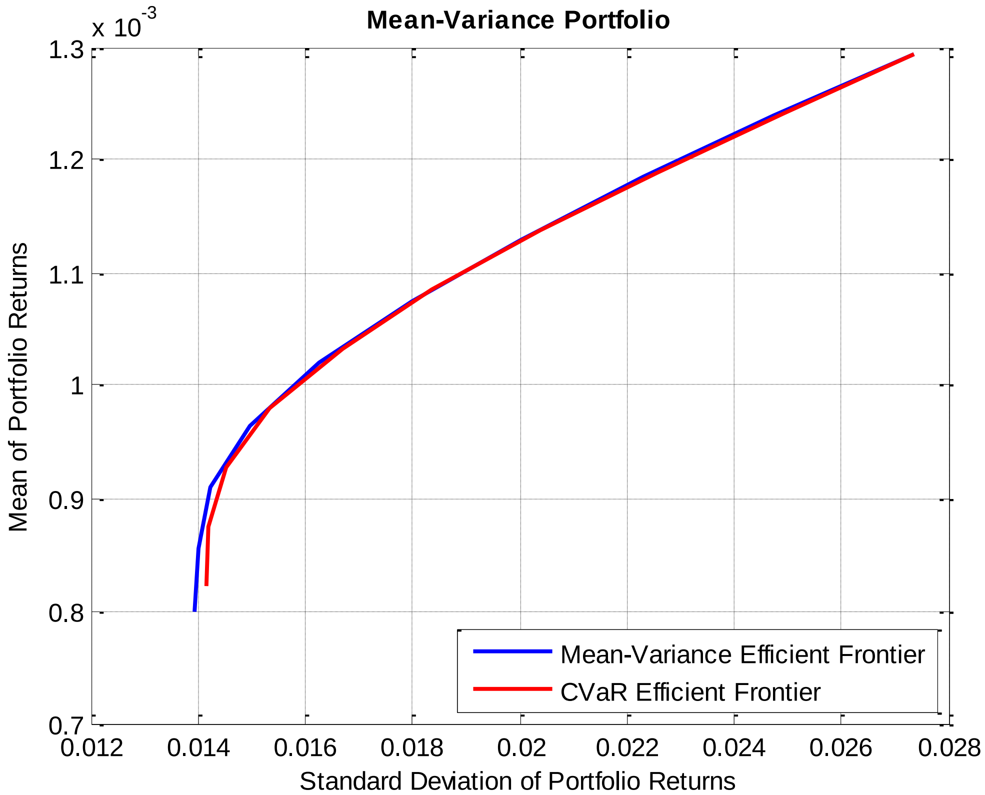
Figure 4. Optimal Portfolio in the Optimisation of the Energy sector



To validate the results above, Figure 5 shows the comparison of the weekly mean variance efficient frontiers of the Mean-Variance Portfolio and the M-CVaR optimisation. The Figure illustrates that some small differences exists between the two optimizations, and this holds especially true for lower levels of portfolio returns.

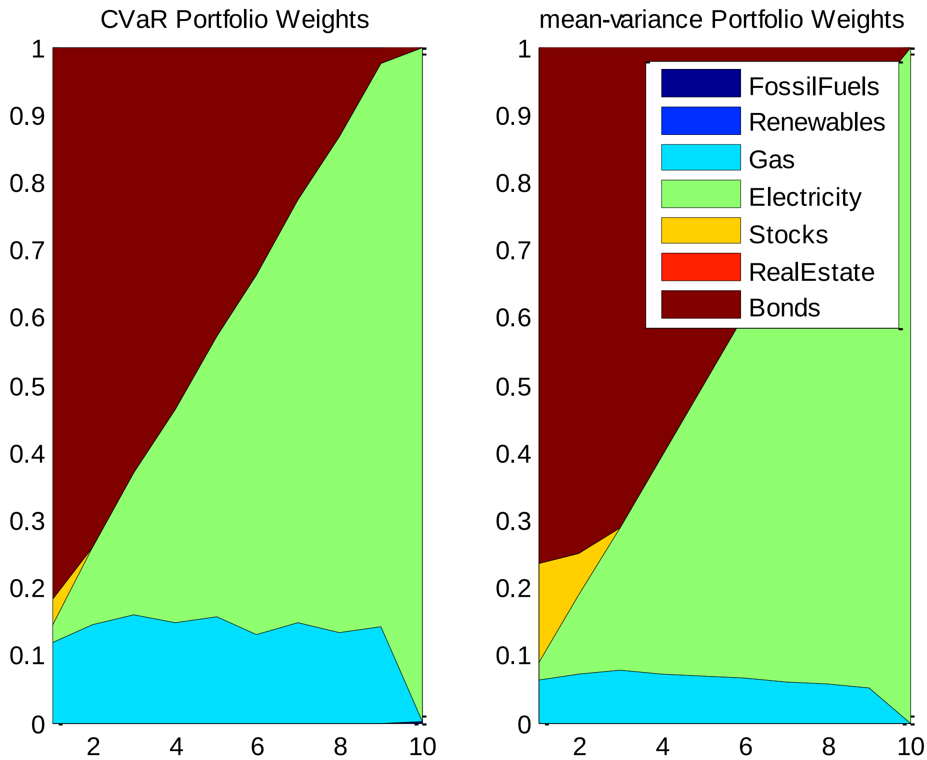
Generally, however, we can observe from the Figure that the results are significantly robust.

Figure 5. Efficient frontiers for Portfolios Mean-Variance and M-CVaR optimization



When comparing the weights of the two optimizations, we observe that using the M-CVaR optimization invests in the same assets as the Mean-Variance optimization, which are: Government Bonds, Gas, Electricity and Stocks. The allocation in certain assets differs as can be seen from Figure 6. In the M-CVaR optimization more is invested in Gas and less in Stocks than the Mean-Variance portfolio weights. The Appendix depicts the differences present in the first portfolios of the efficient frontier and this explains the differences of the frontiers in the lower level of return/risk ratio. However, since our results are analytically significant we can confirm our conclusion that an investor can still benefit even if he/she focuses on a single infrastructure sector.

Figure 6. Weight Comparison for Portfolios Mean-Variance and M-CVaR optimization

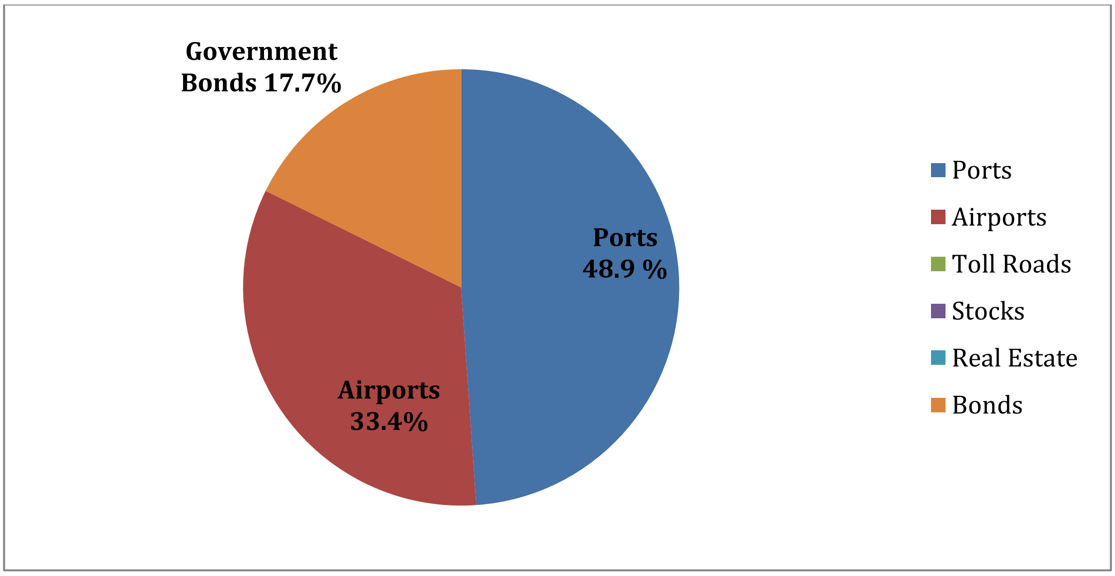


- **Portfolio 4 specialises only in transport sub-sector assets (Airports, Ports and Toll Roads) within a traditional portfolio (e.g., Stocks, Real Estate and Government Bonds)**

In the last considered portfolio, we evaluate the diversification benefits gained by investing only in the Transport sector. For this reason we construct a portfolio that includes only Transport sub-sector assets within a traditional portfolio.

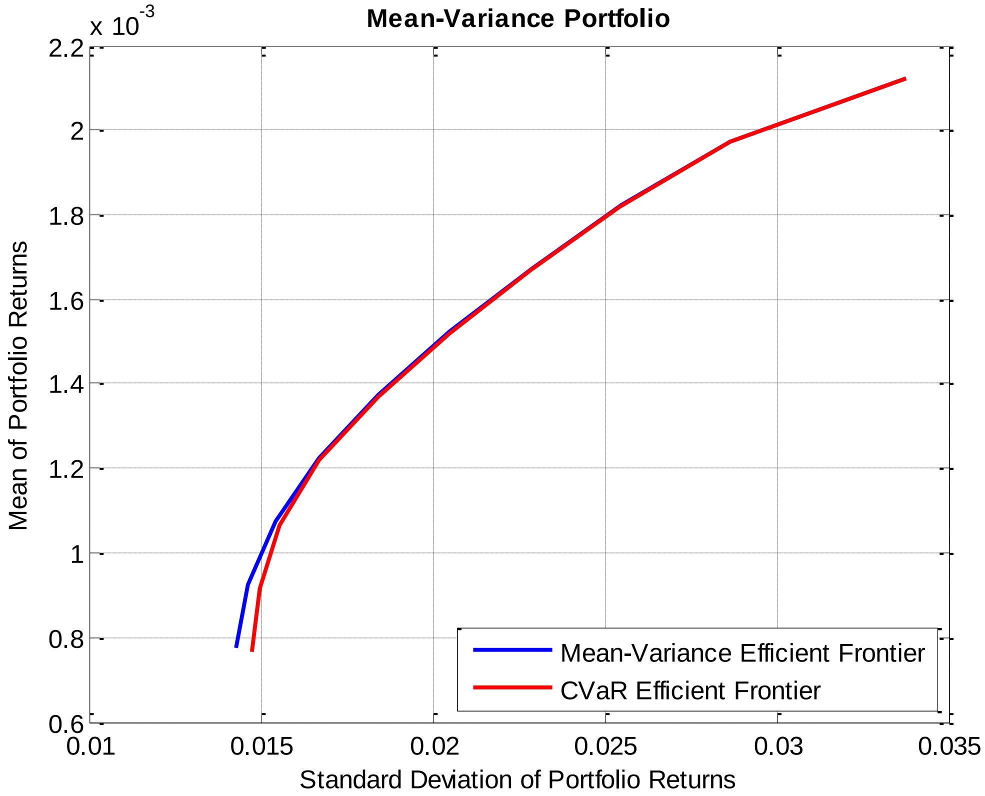
When building a multi-asset portfolio which includes Transport sub-sectors, Stocks, Real Estate and Government Bonds, the maximum Sharp Index achieved is 0.428 and the portfolio invests 48.9% in Ports, 33.4% in Airports, and 17.7% in Government Bonds.

Figure 7. Optimal Portfolio in the Optimisation of the Transport sector



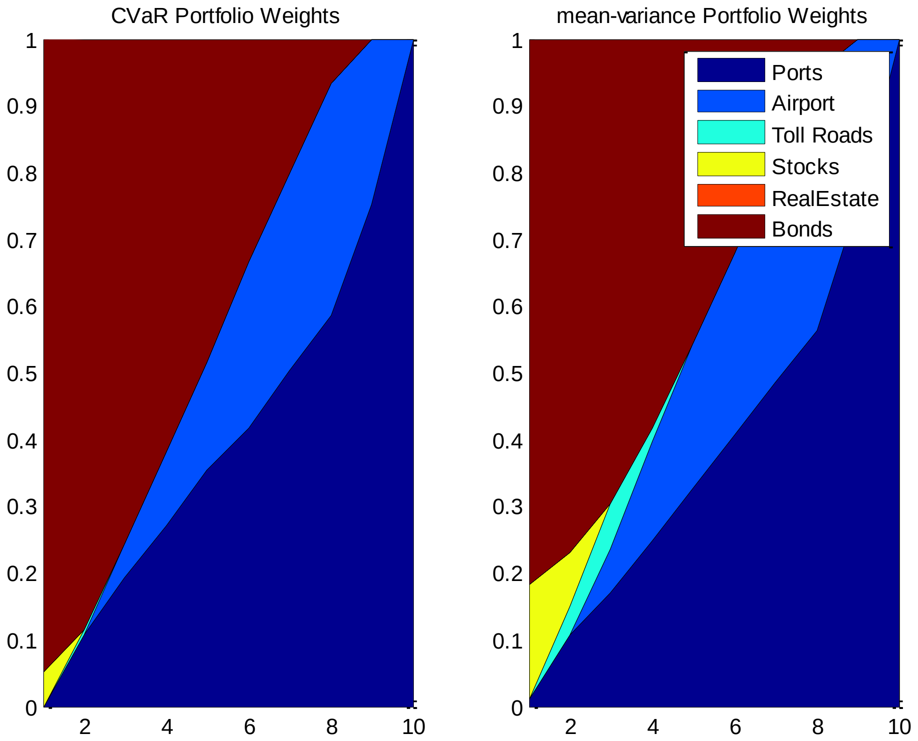
Similar to the two previous optimizations, the results are robust when undertaking the M-CVaR optimization. When comparing the two efficient frontiers (Figure 8), we can observe that the frontiers are very similar apart from the small differences observed at the lower levels.

Figure 8. Efficient frontiers for Portfolios Mean-Variance and M-CVaR optimization



When comparing then the allocation of the assets in the two optimizations we observe from Figure 9, that in the Mean-Variance portfolio weights more is invested in Toll Roads and in Stocks relatively, to the CVaR Portfolio Weights. As can be seen from the efficient frontiers portfolios in the Appendix, the differences in the allocation of certain assets lie in the portfolios at the lower level of the risk/return ratio. However, given the similarity of the results we certainly conclude that investor should only focus and invest in a single sector.

Figure 9. Efficient frontiers for Portfolios Mean-Variance and M-CVaR optimization



6. Conclusions

The importance of infrastructure to the economic welfare of countries is well-recognised among economists, governments and policy makers. The provision of good quality infrastructure is on the agenda of every European government, as infrastructure is the path to increased living standards, economic growth and a means of escaping the recession from which many European governments still suffer. However, the importance of infrastructure investment not only rests with governments that turn to infrastructure as a way to boost their economies. Institutional investors are also paying close attention to infrastructure assets, particularly the European assets. According to Preqin (2013), from the 3700 infrastructure deals that took place since 2008, an annual average of 47% are deals made in European assets.

Despite greater focus and attention being given to European infrastructure assets, little research to date has examined the performance and portfolio implications of this asset class. The economic importance and investment characteristics of infrastructure have been studied mainly at the global level since the late 1980s, with minimal study of different infrastructure sectors (Finkenzeller et al. 2010). As Oyedele (2013, p. 3) has asserted, “infrastructure is an incorporation of many heterogeneous sectors including roads, bridges, ports, power generation, electricity, gas utilities and telecommunications with no two having identical attributes.”

Due to the importance of European infrastructure assets in the global context, and the existence of heterogeneity among different infrastructure sectors and sub-sectors, we have in this paper evaluated the performance of different listed European economic infrastructure assets, i.e., Energy, Utilities, Telecommunications, and Transport over a period that also captures the effects of the financial crisis. The present paper has also provided a performance analysis of Energy and Transport sub-sector indices as a way to more closely scrutinise the behaviour differences and similarities of a selection of sub-sectors. The paper has also examined the significance of including infrastructure in a mixed asset portfolio and has attempted to determine the best way to construct and invest in an infrastructure portfolio.

The results of the European analysis indicate that infrastructure sectors and sub-sectors perform differently and show variations in annual returns and volatilities. In response, greater attention should be paid to specific infrastructure sectors. Not only is knowledge about the performance of different infrastructure sectors crucially important to fund managers, but so is knowledge about each sub-sector equally vital.

Our findings in the second part of the analysis conclude that when the infrastructure sector is combined with other traditional assets, the portfolio yields a higher Sharp Index than the Sharp Index that would be gained by investing in any single asset. Nonetheless, the evidence presented in this study leads to our rejection of the proposition that listed infrastructure can be treated as a separate asset class. We have determined that investing in listed infrastructure is beneficial as long as it is a subset of a traditional portfolio. Furthermore, according to the present research, the creation of a portfolio that invests in a variety of infrastructure sectors is never an optimal solution. For this reason, we have performed a sub-sector Transport and Energy portfolio analysis, and through this analysis we can confirm that there are indeed diversification benefits, even within a specific infrastructure sector.

The recent financial crisis has imposed strict constraints on the availability of public funds, such that limited available resources must be spent as efficiently as possible; governments are thereby required to select and prioritise among various infrastructure projects (Szimba and Rothengatter 2012). This research has shown that, by focussing on one listed infrastructure sector, a fund manager can gain complete knowledge of the performance of the sector and still enjoy diversification benefits. An exciting implication of this finding is that if a country lacks investment in one particular sector, it can invest in this sector and still be able to diversify its infrastructure investment portfolio.

References

Beeferman, W. (2008). “Pension Fund Investment in Infrastructure: A resource Paper.” *Occasional Paper Series*, 3, 1–78.

Bianchi, R., Bornholt, G., Drew M. and Howard, M. (2014). “Long-term U.S. infrastructure returns and portfolio selection” *Journal of Banking & Finance*, 42,314-325.

Colonial First State Global Asset Management (CFS) (2010). “Unlisted Infrastructure: A Proven Performer”. Infrastructure Research Note, London.

CSAM (2010). “Can Infrastructure Investing Enhance Portfolio Efficiency?” White Paper, Crédit Suisse Asset Management, London.

Finkenzeller, K., Dechant, T. and Schafers, W. (2010). “Infrastructure: A new Dimension of Real Estate? An Asset Allocation Analysis.” *Journal of Property Investment & Finance*, 28(4), 263–274.

Gomez, J. and Vasalo, J. (2014). “Comparative Analysis of Road Financing Approaches in Europe and United States.” *Journal of Infrastructure Systems*, 20(3), 1–8.

Hall, J., Henriques, J., Hickford, A., Nicholls, R., Baruah, P., Birkin, M., Chaudry, M., Curtis, T., Eyre, N., Jones, C., Kilsby, C., Leathard, A., Lorenz, A., Malleson, N., McLeod, F., Powrie, W., Preston, J., Rai, N., Street, R., Stringfellow, A., Thoung, C., Tyler, P., Velykiene, R., Watson, G., Watson, J. (2014). “Assessing the Long-Term Performance of Cross-Sectoral Strategies for National Infrastructure.” *Journal of Infrastructure Systems*, 20(3), 1–11.

Idzorek, T. and Armstrong, C. (2009). “Infrastructure and Strategic Asset Allocation: Is Infrastructure an Asset Class?” Ibbotson Associates, Australia.

Inderst, G. (2009). “Pension Fund Investment in Infrastructure.” *Working Papers on Insurance and Private Pensions No.32*, Organisation for Economic Co-Operation and Dependence.

Mackay-Fisher (2012). “Understanding Infrastructure Investments” CEO Forum, Sydney.

Markowitz, H. (1955). "Portfolio Selection," *Journal of Finance*, 7(1) , 77-91.

Markowitz, H. (1959). “ Portfolio Selection: Efficient Diversification of Investments”, John Wiley & Sons, Inc.

Morgan Stanley (2007) “Investing in Infrastructure: A Primer.” *Infrastructure Paper Series*, 2, Morgan Stanley Infrastructure Partners, New York.

Newell, G., Peng, H., and De Francesco, A. (2011). “The performance of unlisted infrastructure in investment portfolios” *Journal of Property Research*, Special Issue: Infrastructure and Regeneration 28(1), 59–74.

Newell, G. and Peng. H. (2007). “The Role of European Infrastructure in Investment Portfolios.” European Real Estate Society (ERES) Conference London June 27–30.

Oyedele, J., McGreal, S., Adair, A. and Ogedengbe, P. (2013). "Performance and Role of European Listed Infrastructure in a Mixed-Asset Portfolio" *Journal of Financial Management of Property and Construction*, 18(2), 160–183.

Oyedele, J. (2013). "Performance and Significance of UK listed infrastructure in a Mixed Asset Portfolio" [pdf] See: http://eres.architexturez.net/system/files/pdf/eres2013_14.content.pdf

Peng, H., and Newell, G. (2007). "The Significance of Infrastructure in Australian Investment Portfolios." *Pacific Rim Real Estate Society Conference*, 13(4),423-450.

Preqin (2014). *Preqin Infrastructure Spotlight, September 2014*, London.

Preqin (2013). *Preqin Special Report: Infrastructure Transaction Activity*, London.

Preqin. (2013). *Preqin Special Report: European Infrastructure*, London.

Rickards, D. (2008). "Global Infrastructure: A Growth Story found in Infrastructure Finance: Trends and Techniques". Edited by H.A. Davis, London, UK: Euromoney Institutional Investor, Ch.1.

Rosenberg Real Estate Equity Funds (RREEF) (2007). "Performance Characteristics of Infrastructure Investments." San Francisco, California.

Rockafellar, R. and Uryasev, S. (2000). "Optimization of Conditional Value-at-Risk," *Journal of Risk*, 2(3) , 21-41.

Rockafellar, R. and Uryasev , S. (2002) "Conditional Value-at-Risk for General Loss Distributions," *Journal of Banking and Finance*, 26 , 1443-1471.

RREEF (2009). "Global Ports: Trends and Opportunities." San Francisco, California.

RREEF (2010). "European Infrastructure Update July 2010." San Francisco, California.

RREEF (2011). "A Compelling Investment Opportunity: The Case July 2011 for Global Listed Infrastructure Revisited." San Francisco, California.

Russ, D., Thambiah, Y., and Foscari, N. (2010). "Can Infrastructure Investing Enhance Portfolio Efficiency?" White Paper, Credit Suisse Asset Management, London.

Szimba, E. and Rothengatter, W. (2012). "Spending Scarce Funds More Efficiently: Including the Pattern of Interdependence in Cost-Benefit Analysis." *Journal of Infrastructure Systems*, 18(4), 242–251.

Appendix

Efficient frontier sets for all the portfolios

- **Portfolio 1 includes only European traditional assets using Mean-Variance Optimisation**

Portfolio Volatility	Stock	Govt. Bonds	Real Estate	Portfolio Return	Sharp Index
9.76%	18.8%	81.2%	0%	4.91%	0.358
10.1%	6.23%	93.8%	0%	5.27%	0.384
10.3%	**0%**	**100%**	**0%**	**5.46%**	**0.392**
11.8%	0%	83.2%	16.8%	5.64%	0.360
13.8%	0%	66.5%	33.5%	5.83%	0.321
16.2%	0%	49.9%	50.1%	6.01%	0.285
18.8%	0%	33.3%	66.7%	6.19%	0.254
21.7%	0%	16.6%	83.4%	6.38%	0.229
24.5%	0%	0%	100 %	6.56%	0.210

- **Portfolio 2 includes the same assets as portfolio 1, plus the addition of all infrastructure sectors using Mean-Variance Optimisation**

Portfolio Volatility	Energy	Telecom	Utilities	Transport	Stocks	Real Estate	Govt. Bonds	Portfolio Return	Sharp Index
9.76%	0%	0%	0%	0%	18.8%	0%	81.2%	4.91%	0.358
10.3%	0%	0%	0%	1.54%	3.92%	0%	94.5%	5.40%	0.389
11.2%	0%	0%	0%	11.3%	0%	0%	88.7%	5.90%	0.400
12.1%	**0%**	**0%**	**0%**	**21.4%**	**0%**	**0%**	**78.6%**	**6.29%**	**0.402**
14.1%	0%	0%	0%	36.6%	0%	0%	63.4%	6.88%	0.389
15.8%	0%	0%	0%	49.3%	0%	0%	50.7%	7.38%	0.377
17.7%	0%	0%	0%	62.0%	0%	0%	38.0%	7.87%	0.364
19.8%	0%	0%	0%	74.7%	0%	0%	25.3%	8.36%	0.352
21.8%	0%	0%	0%	87.3%	0%	0%	12.7%	8.86%	0.341
23.8%	0%	0%	0%	100%	0%	0%	0.%	9.35%	0.334

- **Portfolio 2 includes the same assets as portfolio 1, plus the addition of all infrastructure sectors using Mean Conditional Value-at-Risk Optimisation**

Portfolio	Conditional VaR	Energy	Telecom	Utilities	Transport	Stocks	Real Estate	Bonds	Portfolio Return
10.0%	0.070	0%	0%	0%	0.0%	7.40%	0%	92.6%	5.24%
10.8%	0.075	0%	0%	0%	6.20%	0%	0%	93.8%	5.70%
11.9%	0.084	0%	0%	0%	17.9%	0%	0%	82.1%	6.15%
13.2%	0.094	0%	0%	0%	29.7%	0%	0%	70.3%	6.61%
14.7%	0.105	0%	0%	0%	41.4%	0%	0%	58.6%	7.07%
16.4%	0.118	0%	0%	0%	53.1%	0%	0%	46.9%	7.52%
18.2%	0.132	0%	0%	0%	64.8%	0%	0%	35.2%	7.98%

20.1%	0.146	0%	0%	0%	76.6%	0%	0%	23.4%	8.44%
22.0%	0.159	0%	0%	0%	88.3%	0%	0%	11.7%	8.90%
23.8%	0.173	0%	0%	0%	100%	0%	0%	0.0%	9.35%

- **Portfolio 3 specialises only in the energy sub-sector assets (Natural Gas, Electricity, Fossil fuels, Renewable Energy) within a traditional portfolio using the Mean-Variance Optimisation**

Portfolio Volatility	Fossil Fuels	Renewable Energy	Natural Gas	Electricity	Stocks	Real Estate	Govt. Bonds	Portfolio Return	Sharp Index
10.0%	0%	0%	6.36%	2.49%	14.6%	0%	76.6%	4.16%	0.249
10.1%	0%	0%	7.18%	11.6%	6.31%	0%	74.9%	4.44%	0.276
10.3%	0%	0%	7.70%	21.2%	0%	0%	71.1%	4.73%	0.299
10.8%	**0%**	**0%**	**7.29%**	**32.1%**	**0%**	**0%**	**60.6%**	**5.02%**	**0.311**
11.7%	0%	0%	6.87%	43.1%	0%	0%	50.0%	5.30%	0.311
13.0%	0%	0%	6.46%	54.0%	0%	0%	39.5%	5.59%	0.303
14.4%	0%	0%	6.05%	65.0%	0%	0%	29.0%	5.87%	0.292
16.1%	0%	0%	5.63%	76.0%	0%	0%	18.4%	6.16%	0.280
17.8%	0%	0%	5.22%	86.9%	0%	0%	7.87%	6.44%	0.268
19.7%	0%	0%	0%	100%	0%	0%	0%	6.74%	0.258

- **Portfolio 3 specialises only in the energy sub-sector assets (Natural Gas, Electricity, Fossil fuels, Renewable Energy) within a traditional portfolio using the Mean- Conditional Value-at-Risk Optimisation**

Volatility	C-VaR	Fossil Fuels	Renewable Energy	Natural Gas	Electricity	Stocks	Real Estate	Government Bonds	Return
10.2%	0.033	0%	0%	11.8%	2.83%	3.81%	0%	81.6%	4.28%
10.2%	0.033	0%	0%	14.5%	11.3%	0%	0%	74.2%	4.55%
10.5%	0.035	0%	0%	15.9%	21.0%	0%	0%	63.1%	4.82%
11.1%	0.037	0%	0%	14.6%	31.8%	0%	0%	53.6%	5.09%
12.1%	0.041	0%	0%	15.5%	41.7%	0%	0%	42.8%	5.37%
13.3%	0.045	0%	0%	13.1%	53.1%	0%	0%	33.9%	5.64%
14.7%	0.050	0%	0%	14.8%	62.6%	0%	0%	22.6%	5.91%
16.3%	0.056	0%	0%	13.3%	73.5%	0%	0%	13.2%	6.18%
18.0%	0.061	0%	0%	14.3%	83.4%	0%	0%	2.35%	6.46%
19.7%	0.068	0%	0%	0%	100%	0%	0%	0%	6.74%

- **Portfolio 4 includes Transport sub-sector assets (Airports, Ports, and Toll Roads) within a traditional portfolio using Mean-Variance Optimisation**

Portfolio Volatility	Ports	Airports	Toll Roads	Stocks	Real Estate	Bonds	Portfolio Return	Sharp Index
10.3%	1.17%	0%	0%	17.2%	0%	81.6%	4.03%	0.230
10.5%	10.7%	0%	4.22%	8.19%	0%	76.9%	4.80%	0.299
11.1%	17.0%	6.65%	6.75%	0%	0%	69.6%	5.58%	0.353
12.0%	24.8%	14.9%	1.84%	0%	0%	58.4%	6.36%	0.391
13.3%	32.7%	21.6%	0%	0%	0%	45.7%	7.14%	0.413
14.8%	40.6%	27.3%	0%	0%	0%	32.1%	7.92%	0.424
16.6%	**48.9%**	**33.4%**	**0%**	**0%**	**0%**	**17.7%**	**8.76%**	**0.428**
18.3%	56.4%	38.8%	0%	0%	0%	4.81%	9.48%	0.426
20.7%	75.2%	24.8%	0%	0%	0%	0%	10.3%	0.416
24.3%	100%	0%	0%	0%	0%	0%	11.1%	0.386

- **Portfolio 4 includes Transport sub-sector assets (Airports, Ports, and Toll Roads) within a traditional portfolio using Mean- Conditional Value at Risk Optimisation**

Portfolio Volatility	C-VaR	Ports	Airports	Toll Roads	Stocks	Real Estate	Bonds	Portfolio Return
10.6%	0.034	0%	0%	0%	5.1%	0%	94.9%	3.98%
10.8%	0.035	10.7%	0%	0.8%	0%	0%	88.5%	4.77%
11.2%	0.038	19.3%	4.98%	0%	0%	0%	75.7%	5.55%
12.0%	0.041	27.1%	11.0%	0%	0%	0%	61.9%	6.33%
13.3%	0.045	35.3%	16.3%	0%	0%	0%	48.4%	7.12%
14.7%	0.051	41.7%	24.8%	0%	0%	0%	33.5%	7.90%
16.5%	0.057	50.3%	29.4%	0%	0%	0%	20.3%	8.68%
18.3%	0.064	58.5%	34.8%	0%	0%	0%	6.7%	9.47%
20.6%	0.071	75.1%	24.9%	0%	0%	0%	0%	10.3%
24.3%	0.084	100%	0%	0%	0%	0%	0%	11.1%