

Performance and Significance of UK Listed Infrastructure in a Mixed-Asset Portfolio

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Abstract

Purpose of Paper- This paper examines the performance of UK listed infrastructure over a unique investment period covering the global financial crisis and investigates the significance of UK infrastructure in a multi-asset portfolio. The analysis reveals the level of correlation of UK infrastructure with other major assets classes and substantiates the potential diversification benefits of including UK infrastructure within a mixed asset portfolio.

Research Design and Data-The study uses monthly investment return indices obtained from Thomson Reuters DataStream over a ten year period (2001-2010). The paper analysed the UK listed infrastructure investment return characteristics including average annual return, annual risk, Sharpe indices, mean variance portfolio and maximum return portfolio and computes the efficient portfolio frontiers using the risk solver optimization tool.

Research Findings- The performance results show that UK infrastructure produced better risk-return trade-offs than those of UK property, private equity, hedge funds and UK stocks over the period 2001-2010. Overall, for the ten year period, UK Water was the best performing asset class outperforming all other asset classes having the highest Sharpe ratio of 0.75.

Research Implication- Using the monthly return indices over the ten year period, UK listed infrastructure investment was found to play a consistently significant role in the optimality of mixed-asset portfolios. However, the diversification benefits were more return enhancing than risk reducing, offering investors a platform for matching investment objectives with expectations resulting from a better understanding of the characteristics of UK listed infrastructure investments.

Originality- As investors seek better understanding of the performance of infrastructure across the globe, with most previous studies focusing on Australia, US and China, the paper makes significant contribution to the body of knowledge by focusing on UK, a promising investment space for infrastructure industry. Also, given the debate surrounding the emergence of infrastructure as a separate asset class, the paper particularly projects the potential benefits of investing in UK listed infrastructure, offering investors a distinctive platform to launch into a vibrant asset class.

Keywords- Portfolio Diversification, UK Listed Infrastructure, Efficient Frontiers

1. Introduction

Investment in infrastructure has evolved as one of the most appealing alternative asset classes, particularly attractive to institutional investors searching for higher diversification benefits, higher-yielding and stable investments. Also, compelled by the growing fiscal budgetary constraints, governments across jurisdiction are raising much needed revenue through the monetization of their existing infrastructure assets, thereby increasing the supply of such investments, RREEF (2007). As a result, increasing number of opportunities in private infrastructure investments are emerging globally, extending across investments in the physical capital assets including transport, housing, energy and utility facilities, healthcare and educational facilities, communications, and judicial and correctional facilities, RREEF (2006).

Apart from the institutional appeal for infrastructure investments, the infrastructure sector gained renewed scale of importance during the global financial crisis which started in 2007 as most of the fiscal stimulus announced by governments globally targeted infrastructure as means to combat severe recession, highlighting the critical role the sector plays in economic recovery and development, RREEF, (2011). Regardless of the financial turmoil which severely affected the European markets, investment in the UK infrastructure assets continues to be an attractive option. Although infrastructure transactions have generally been modest, the UK Government is increasingly projecting infrastructure as one of the key drivers for the UK's economic recovery. One of the mainstays of this ingenuity is the UK Government's push to make the sector more attractive for both the local and international investors, Smith (2012).

The presence of the private sector in the UK infrastructure industry is apparent with a substantial part of UK infrastructure resources (\$71.91bn) delivered through the public private partnership (PPP) model (Table 1). In terms of overall spending on infrastructure, the UK infrastructure space is attractive for investors and the leading destination within Europe and second to the United States within the global ranking (Table 2).

Table 1. Ten Largest PPP Transactions (2005-2010 H1)

Country	Value (\$USDm)	No. of Deal	Ranking	Percentile
United Kingdom	71906.98	558	1	100.00%
Spain	33042	134	2	98.90%
Australia	27539.33	82	3	97.80%
United States	20206.93	61	4	96.70%
France	17402.78	130	5	95.60%
Portugal	16193.06	54	6	94.60%
Canada	15695.93	96	7	93.50%
Greece	14044.02	51	8	92.40%
Mexico	12216.54	42	9	91.30%
South Korea	12154.63	27	10	90.30%

Note: Ranking and percentile based on value

Table 2. Ten Largest Global Infrastructure Transactions (2005-2010 H1)

Country	Value (\$USDm)	No. of Deal	Ranking	Percentile
United States	254332.1	834	1	100.00%
United Kingdom	186653.9	856	2	99.50%
Australia	123349.6	318	3	99.00%
Spain	119445.9	543	4	98.50%
Saudi Arabia	92793.17	58	5	98.10%
India	72354.56	222	6	97.60%
Italy	66838.61	218	7	97.10%
France	64052.91	221	8	96.70%
Canada	63387.56	245	9	96.20%
Brazil	58293.79	157	10	95.70%

Note: Ranking and percentile based on value

As a reflection of mounting demand for infrastructure investments by both the public and private sectors, there now exists an increasing number of vehicles to access infrastructure including direct investments in infrastructure projects, listed infrastructure funds, listed infrastructure companies and unlisted infrastructure funds, Peng and Newell (2007). However, despite this increased interest in infrastructure investment, there is a dearth of knowledge regarding the feasible impact of infrastructure investment as an investment strategy for enhanced portfolio performance. As such, the essence of this paper is to critically analyse the significance of listed infrastructure investment in a mixed-asset portfolios in the United Kingdom, reflecting significant issues such as the risk-adjusted performance of UK listed infrastructure over a ten year timeframe 2001-2010, as well as the potential portfolio diversification benefits which UK listed infrastructure offers.

2. Concept of Infrastructure Investments

The concept of infrastructure varies across a wide range of assets and the definition of infrastructure investment seems intuitive (Inderst, 2009). Infrastructure is characterized by the array of assets and primary services that are fundamental to the success and economic development of any community (Evans, 2009). Infrastructure is comprised of vastly heterogeneous assets with no two having identical attributes. It is an incorporation of varying sectors including roads, bridges, dams, ports, airports, power generation and distribution, transmission of electricity, water and gas utilities, and communications. Each sector has its own distinct performance behavior (RREEF, 2007).

In functional terms; specifically, in terms of the uses of the assets and services that are necessary for the proper functioning of global economies. The category of economic infrastructure is used to describe essential services such as transportation (toll-roads, bridges, tunnels, airports, seaports, and rail networks), as well as common utilities such as gas distribution networks, electricity and renewable energy production and distribution, and water treatment and distribution facilities (Russ et al, 2010). Social infrastructure assets are characterized by improvement, operation and maintenance of government-occupied assets, such as facilities required for security, justice, correctional facilities, energy, immigration, taxation and customs which falls within the social infrastructure space, in addition to health care and education at federal, state and local levels (Evans, 2009).

A rather more in depth description divides economic infrastructure into two categories: transportation and utilities. The first category includes toll roads, bridges, tunnels, parking facilities, railroads, rapid transit links, airports, refueling facilities, seaports. The second encompasses electricity generation and transmission, gas and water distribution, sewage treatment, broadcast and wireless towers, telecommunication, cable networks, and satellite networks (Beeferman, 2008).

Each infrastructure category has its own distinctive performance history. The performance of infrastructure assets is also closely tied to the stage of the assets lifecycle, i.e. greenfield development versus a brownfield infrastructure which defines mature infrastructure assets with proven demand patterns (RREEF, 2007). Regardless of these differences, infrastructure resources have certain characteristics in common, including:

- Economic: naturally monopolistic markets
- Regulated markets: controlled charges and fee increases (e.g. toll roads), regulated utilities
- Long-lived assets: Concessions from public authorities: long-dating contracts (e.g. hospitals)
- Real assets with stable demand

As a consequence of the above infrastructure features, the investment community infers a number of attractive investment characteristics of infrastructure assets including;

- Stable and predictable cash flows
- Long term income streams
- Inflation-linked (helping with liability-matching)
- Returns insensitive to the fluctuations in business, interest rates, stock markets
- Low risk investments - relatively low default rates
- Low correlations with other assets classes (offering diversification potential)
- Low volatility
- Socially responsible investing (SRI) (providing public goods essential to society) (Inderst, 2009; Bitschy et al, 2010; Evans, 2009 and Newell et al, 2009).

While earlier research has covered the performance profile of infrastructure across Australia (Finkenzeller et al, 2010; Peng and Newell, 2007; Newell et al 2011); China (Newell et al, 2009); US (Newell and Peng, 2008) and India (Singhal et al. 2011), even at a larger scale covering European infrastructure (RREEF Research, 2010; Newell and Peng, 2007); and global infrastructure (RREEF Research (2009), there is a dearth of infrastructure performance analysis for the UK infrastructure market. Considering the significance position of UK within the infrastructure investment landscape, as a developed infrastructure market which reflects a leading role within the European and global infrastructure space, hence, the focus of this paper is on the UK infrastructure market with emphasis on listed investment, showcasing the performance of UK listed infrastructure and its role in a mixed asset portfolio over a unique financial timeframe 2001-2010.

3. Research Methodology

A quantitative research method is adopted for this study, obtaining secondary historical time series data from Thomson Reuters. The set of data include UK infrastructure investment returns over a ten years timeframe (2001-2010). The range of monthly return indices obtained for the UK infrastructure asset performance assessment includes; The UK asset classes include: UBS UK infrastructure, UBS UK infrastructure and utilities, UBS UK utilities, S&P UK property, UK DataStream private equity, UK DataStream hedge fund, UK DataStream stocks and UK bonds-Total All Lives Government Index. While the UBS UK ports and UBS UK water constitutes the UK infrastructure sub-sectors.

The risk-return performance analysis of these data substantiates the average annual returns, annual risk/volatility and their Sharpe indices. The analysis also show how the various infrastructure sectors correlate with each other and other investment sectors such as stocks, bonds, property, private equity and hedge fund.

In order to perform a robust analysis, the data series used for the paper are the monthly return indices represented by the equations;

$$E(r_p) = 12 \left[\frac{1}{n} \sum_{i=1}^n w_i E(r_i) \right] \quad \dots \text{eq. (1)}$$

Where:

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

r_i = Rate of return on ith/individual security and

$\sum_{i=1}^n w_i = 1$ (The sum of n weights in portfolio must be one).

Similarly, the portfolio risk is given as;

$$\text{Var}(r_p) = \sum_{i=1}^n w_i^2 SD_i^2 + 2 \sum_{j=1}^n \sum_{i=1}^n w_i w_j r_{ij} SD_i SD_j \text{ for } i \neq j \quad \dots \text{eq. (2)}$$

$$SD(r_p) = \sqrt{\text{Var}(r_p)} \quad \dots \text{eq. (3)}$$

Adjusting for monthly indices gives;

$$SD(r_p) = \sqrt{12 \text{Var}(r_p)} \quad \dots \text{eq. (4)}$$

Where:

$\text{Var}(r_p)$ = Portfolio variance

r_{ij} = Correlation coefficient between the ith and jth variables

$SD(r_p) = \sqrt{\text{Var}(r_p)}$ = Standard deviation of portfolio

SD_i = Standard deviation of the ith variable

SD_{ij} = Covariance of ith and jth variables

Based on the available data set for the UK listed infrastructure asset classes, the role of UK infrastructure within a multi asset portfolio is examined for potential diversification benefits and includes the following portfolios constructed with the aid of the risk solver optimization tool:

Portfolio #1- UK stocks and Bonds

Portfolio #2- (Stocks, Private Equity, Bonds, Hedge Fund and Property) - Without UK Infrastructure

Portfolio #3- With UK Infrastructure (Unconstrained)

Portfolio #4- With UK Infrastructure (Constrained)

Portfolio #5- UK Infrastructure Sub-sectors, UK Stocks and UK Bonds- The available data set for the UK infrastructure sub-sectors include UK ports and UK water and these are tested with the more conventional asset classes (UK stocks and UK bonds).

Heuristically, the efficient frontiers are constructed by applying the following procedure as shown by Byrne and Lee (1994):

1. Compute the end points of the efficient frontiers (EF) by (a); finding the maximum return portfolio and record the risk (σ_1) = upper end of the EF; (b) Find the minimum risk (σ_2) portfolio and record the return = lower end of the EF.
2. Calculate the difference between σ_1 and σ_2 ($\sigma_2 - \sigma_1$) and split into a sufficient number of points to create a reasonable graph.
3. Determine the maximum return combination for each of these risk levels. At this stage the 'Risk Solver Platform 11' has to be applied a reasonable number of times
4. The efficient frontier is constructed by graphing these returns against the risks.

4. UK Infrastructure Performance Analysis

Committed investor capital in UK listed infrastructure and the combined infrastructure and utilities series as at December 2010 stood at \$5.86bn and \$106.21bn respectively (Thomson Reuters, 2010), representing 7.94% and 22.61% of the European equivalents. In this context, UK listed infrastructure capital is similar to other UK asset classes such as private equity (\$5.14bn) and hedge fund (\$6.80bn). Comparative performance of UK infrastructure and other major asset classes is examined for the ten year period (2001-2010), showing monthly return trends and related volatility.

Based on risk-adjusted performance, UK infrastructure showed a moderate performance over the ten year timeframe posting the second highest annualised return of 12.16% and a moderate risk exposure of 20.02% (Table 3).

Table 3 UK Infrastructure Performance Analysis-Full Period (2001-2010)

UK Listed Assets -Full Period	Market	No. of Equities	Annualised Return	Volatility	Sharpe Index	Rank	Percent
	Value (\$Mn)						
UBS UK Infra	5,864	2	12.16%	20.02%	0.5	5	55.50%
UBS UK Infra and Utilities	106,212	11	10.62%	15.07%	0.56	3	77.70%
UBS UK Utilities	100,348	9	10.55%	15.34%	0.55	4	66.60%
S&P UK Property	37,734	26	2.41%	24.38%	0.01	9	11.10%
UK-DS Priv. Equity	5,136	na	-0.51%	30.01%	-0.24	10	0.00%
UK-DS Hedge Fund	6,804	na	4.14%	11.21%	0.18	7	33.30%
UK-Stock Market	1,823,204	na	3.54%	16.59%	0.08	8	22.20%
UK Total All Lives							
Govt. Index	794,320	na	5.34%	5.35%	0.6	2	88.80%
UBS UK Ports	995	1	10.96%	27.98%	0.32	6	44.40%
UBS UK Water	10,137	3	15.54%	17.77%	0.75	1	100.00%

This resulted in a Sharpe ratio of 0.50, outperforming UK stocks (Sharpe ratio = 0.08) and the other alternative asset classes including property (Sharpe ratio = 0.01), private equity (Sharpe ratio = -0.24) and hedge funds (Sharpe ratio = 0.18). A similarly robust performance was seen by the UK infrastructure and utilities (Sharpe ratio = 0.56) and utilities (Sharpe ratio = 0.55).

The UK water sub-sector demonstrated a more superior performance, emerging as the overall best asset class (Sharpe ratio = 0.75) during the ten year timeframe, posting the highest annualised return of 15.54% but with a high level of volatility (17.77%) and outperforming the UK bonds (Sharpe ratio = 0.60). Performance by UK ports (Sharpe ratio = 0.32) was the lowest in the infrastructure sector (percentile rank = 44.40%) though outperforming UK stocks market, property, private equity and hedge funds.

4.1 UK Sub-Period Performance Analysis

The dynamics of UK infrastructure performance relative to other asset classes is more fully assessed by the sub-period performance analysis: the pre-GFC, GFC and the post-GFC periods.

4.1.1 Pre-GFC Period

The pre-GFC period shows a more robust performance across all asset classes. UK infrastructure shows a consistently strong performance with a return of 12.83% at a volatility of 18.26%. The resultant Sharpe ratio is 0.55 (Table 4). UK infrastructure showed a superior performance over stocks (Sharpe ratio = 0.16), private equity (Sharpe ratio = -0.05), hedge funds (Sharpe ratio = 0.27) and bonds (Sharpe ratio = 0.34). However, the UK property outperformed infrastructure during the pre-GFC period with an annualised return of 15.82% and a volatility of 17.16%. and a Sharpe Index of 0.76.

Table 4 UK Infrastructure Performance Analysis- Pre-GFC Period (Q1 2001-Q3 2007)

UK Listed Assets -Pre-GFC Period	Annualised Return	Volatility	Sharpe Index	Rank	Percent
UBS UK Infrastructure	12.83%	18.26%	0.55	6	44.40%
UBS UK Infra and Utilities	14.06%	13.43%	0.84	3	77.70%
UBS UK Utilities	14.10%	13.64%	0.83	4	66.60%
S&P UK Property	15.82%	17.16%	0.76	5	55.50%
UK-DS Private Equity	1.47%	24.90%	-0.05	10	0.00%
UK-DS Hedge Fund NAV	5.32%	9.33%	0.27	8	22.20%
UK-Stock Market	4.88%	13.44%	0.16	9	11.10%
UK Total All Lives Govt. Index	4.45%	4.55%	0.34	7	33.30%
UBS UK Ports	20.96%	16.08%	1.13	1	100.00%
UBS UK Water	19.88%	15.67%	1.09	2	88.80%

The UK infrastructure sub-sectors were the best performing asset classes during the pre-GFC period, outperforming other asset classes including property, stock and bonds. UK ports had the highest annualised return of 20.96% and a volatility of 16.08% over this period and the highest Sharpe ratio of 1.13 followed by UK water (Sharpe ratio = 1.09).

4.1.2 GFC Period

As highlighted in Table 5, apart from UK bonds, investment in UK infrastructure demonstrated more resilient characteristics to the GFC compared to the other UK asset classes. UK bonds were the best performing asset class (Sharpe ratio = 0.92) with an annualised return of 8.07% and a volatility of 7.32% and UK infrastructure was the only other asset class posting positive annualised returns (3.83%) during the global financial crisis, though at a relatively high level of volatility (28.76%) and a low Sharpe ratio of 0.09. Nevertheless, infrastructure outperformed other asset classes including UK stocks (Sharpe ratio = -0.64), property (Sharpe ratio = -1.14), private equity (Sharpe ratio = -0.86) and hedge funds (Sharpe ratio = -0.42).

Table 5 UK Infrastructure Performance Analysis- GFC Period (Q4 2007-Q2 2009)

UK Listed Assets - GFC Period	Annualised Return	% Change	% Volatility	% Increase	Sharpe Index	Rank	Percent
UBS UK Infra	3.83%	-70.15	28.76%	57.5	0.09	2	88.80%
UBS UK Infra and Utilities	-6.00%	-142.67	20.77%	54.65	-0.35	4	66.60%
UBSUK Utilities	-6.35%	-145.04	21.04%	54.25	-0.36	5	55.50%
S&PUK Property	-44.35%	-380.34	40.17%	134.09	-1.14	10	0.00%
UK-DS Private Equity	-40.58%	-	48.99%	96.75	-0.86	9	11.10%
UK-DS Hedge Fund	-6.62%	-224.44	18.80%	101.5	-0.42	6	44.40%
UK-Stock Market	-14.39%	-394.88	24.41%	81.62	-0.64	8	22.20%
UK Total All Lives Govt. Index	8.07%	81.35	7.32%	60.88	0.92	1	100.00%
UBS UK Ports	-26.17%	-224.86	46.09%	186.63	-0.6	7	33.30%
UBS UK Water	-6.46%	-132.49	23.64%	50.86	-0.33	3	77.70%

4.1.3 Post-GFC Period

The recovery process noticed for the UK tended to follow a similar trend to those of the global and European asset classes characterised by increasing annualised returns and decreasing volatilities. However, the UK infrastructure and infrastructure related asset classes saw a different recovery dynamics relative to the other UK asset classes. Although investment in UK infrastructure (Sharpe ratio = 1.20) was seen to slightly underperform UK stocks (Sharpe ratio =1.22), UK hedge funds was best performing asset class with a Sharpe ratio of 1.96 (Table 6) outperforming infrastructure during the post-GFC period due largely to a relatively low risk-return trade off.

Table 6 UK Infrastructure Performance Analysis- Post-GFC Period (Q3 2009-Q4 2010)

UK ASSETS -Post-GFC Period	Annualised Return	% Increase	% Volatility	% Decrease	Sharpe Index	Rank	Percent
UBS UK Infra	19.48%	408.62	16.07%	44.12	1.2	4	66.60%
UBS UK Infra and Utilities	16.56%	376	14.29%	31.2	1.15	5	55.50%
UBS UK Utilities	16.34%	357.32	14.84%	29.47	1.09	7	33.30%
S&P UK Property	19.89%	144.85	22.47%	44.06	0.88	9	11.10%
UK-DS Private Equity	21.49%	152.96	18.95%	61.32	1.13	6	44.40%
UK-DS Hedge Fund	12.39%	287.16	6.26%	66.7	1.96	1	100.00%
UK-Stock Market	21.96%	252.61	17.87%	26.79	1.22	3	77.70%
UK Total All Lives Govt. Index	6.24%	22.68	6.21%	15.16	0.99	8	22.20%
UBS UK Ports	21.00%	180.24	40.29%	12.58	0.52	10	0.00%
UBS UK Water	25.22%	490.4	18.61%	21.28	1.35	2	88.80%

However, UK infrastructure saw a relatively strong recovery from the global financial crisis with an annualised return of 19.48% (post-GFC) compared to 3.83% (GFC) and a reduced level of volatility (16.07%) compared to 28.76% previously. This indicates a remarkable decrease of 44.12% in level of risk exposure. At a sub-sector level, UK water had a relatively low volatility of 18.61% and the highest annualised return (25.22%) compared to the negative return (-6.46%) in the GFC period. The relatively high performance Sharpe ratio (1.35) of UK water during the post-GFC period saw it emerged as the best performing asset class after UK hedge fund. In contrast, while all other UK infrastructure asset classes

outperformed bonds, investment in UK ports during the post-GFC was least performing sector (Sharpe ratio = 0.52), with a high annualised return of 21.00% offset the level of volatility.

5. Diversification Benefits of UK Infrastructure Investment

Correlation coefficients of UK infrastructure with other major UK assets indicate the level of potential diversification benefits offered within a mixed asset portfolio and contribute significantly to debate surrounding the emergence of infrastructure as a separate asset class from a national perspective. UK infrastructure shows a relatively weak to moderate correlation across the other asset classes. For the ten year timeframe, the correlation between UK infrastructure and UK stocks ($r = 0.59$) is positive and moderate suggesting limited diversification opportunities (Table 7). There is increased scope for diversification benefits with other asset classes, particularly with UK bonds which offered the weakest correlation with UK infrastructure ($r = 0.08$). Other areas of valuable diversification benefits are with UK hedge funds ($r = 0.11$) and to a lesser degree with UK private equity ($r = 0.38$), and UK property ($r = 0.44$).

Table 7 UK Inter-Assets Correlation (2001-2010)

UK Assets - Full Period	UK Infra	Infra and Util	Utilities	Ports	Water	Stock	Private Eqty.	Bonds	HF	Property
UK Infra	1									
Infra and Util	0.58*	1								
Utilities	0.50*	0.99*	1							
Ports	0.57*	0.47*	0.44*	1						
Water	0.32	0.76*	0.78*	0.34	1					
Stock	0.59*	0.60*	0.57*	0.55*	0.38	1				
P. Eqty.	0.38*	0.35	0.32	0.41*	0.30	0.7*3	1			
Bonds	0.08	0.06	0.07	0.14	0.01	-0.14	-0.21	1		
H Fund	0.11	0.10	0.09	0.12	0.02	0.27	0.29	-0.28	1	
Property	0.44*	0.57*	0.55*	0.60*	0.49*	0.70*	0.64*	0.07	0.11	1

Note: *Significant correlation ($P < 5\%$).

Across the other UK infrastructure sub-sectors, water is seen to offer the highest diversification benefits, given the weak correlation with the other assets classes with weak correlations with bonds ($r = 0.01$) and hedge funds ($r = 0.02$) with hedge funds. The other UK infrastructure related asset classes appear to offer less potential diversification benefits, for instance, the correlation between UK infrastructure and utilities and property ($r = 0.57$), utilities and property ($r = 0.55$) and UK ports and property ($r = 0.60$) are all positive and of moderate strength.

6. Role of UK Infrastructure in Multi-Asset Portfolios

The previous section revealed possible diversification benefit of UK infrastructure given the weak to moderate correlation with other major UK asset classes. In assessing the role of UK infrastructure within a mixed asset portfolio, a number of portfolio scenarios are constructed under different portfolio risk-return combinations for the ten year period (2001-2010) including:

Portfolio #1- UK stocks and bonds

Portfolio #2- Stocks, Private Equity, Bonds, Hedge Funds and Property

Portfolio #3- As portfolio #2 with UK Infrastructure (Unconstrained)

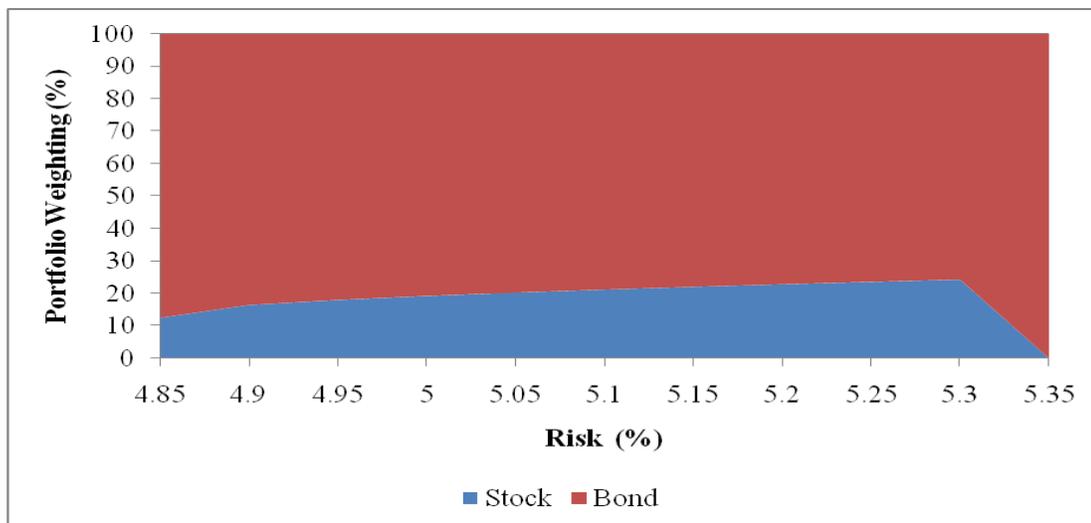
Portfolio #4- As portfolio #2 with UK Infrastructure (Constrained)

Portfolio #5- UK Infrastructure Sub-sectors, UK Stock and UK Bonds

The portfolio combination including UK stocks and bonds (Portfolio #1) shows only modest diversification benefit, given that investment in UK bonds alone were providing a Sharpe ratio of 0.6 while that for UK stocks was relatively weak; Sharpe ratio of 0.09, volatility of 16.59% and an annualised return of 3.54%. From the efficient sets (Table 8), the optimal portfolio combination of 12.50% UK stocks and 87.50% bonds revealed a 5% diversification gain with a return of 5.3% and a risk of 4.85%. The diversification benefit is largely evident in terms of risk reduction rather than return enhancement. The portfolio weighting relative to risk revealed the dominance of bonds investment, the highest allocation to stock (24.34%) was at the second efficient set with a portfolio risk of 5.3% (Figure 1) with bonds having their least allocation of 75.66%.

Table 8 Portfolio #1- UK Stocks and Bonds

	MVP (%)	Stock	Bonds	MRP	Portfolio (PSI)	Sharpe Index
1	5.35	0	100	5.34	0.60	
2	5.3	24.34	75.66	5.22	0.58	
3	5.25	23.64	76.36	5.23	0.59	
4	5.2	22.90	77.10	5.23	0.60	
5	5.15	22.11	77.89	5.24	0.60	
6	5.1	21.26	78.74	5.25	0.61	
7	5.05	20.33	79.67	5.25	0.62	
8	5	19.29	80.71	5.26	0.63	
9	4.95	18.06	81.94	5.27	0.63	
10	4.9	16.49	83.51	5.28	0.64	
11	4.85	12.50	87.50	5.3	0.65	

Figure 1 UK Stocks and Bonds Allocation Relative to Risk

Further diversification benefit is achieved as more asset classes are included (at the moment excluding the UK infrastructure) (Table 9). Achieving a higher performance level compared to investment in the best performing individual asset class (bonds) is possible within the second efficient set (PSI = 0.62) to the eleventh (PSI = 0.75) efficient set. The diversification gain is seen to have increased from 5% previously to 15% at the optimal portfolio (highest PSI = 0.75) as identified at the eleventh efficient set with the minimum risk 4.11% and a portfolio return of 5.22%. The optimal portfolio is achieved from a portfolio combination including 5.31% stock, 0.23% private equity, 73.62% bonds and

20.84% hedge funds. The diversification gain is due largely to risk reduction (-23.18%) than return enhancement.

Table 9 Portfolio #2- Without Infrastructure

	MVP (%)	Stock	Private Equity	Bonds	Hedge Fund	Property	MRP (%)	(PSI)
1	5.35	0	0	100	0	0	5.34	0.60
2	5.23	0	0	94.76	0.89	4.35	5.35	0.62
3	5.10	0	0	93.41	2.48	4.11	5.34	0.63
4	4.98	0	0	92.01	4.14	3.84	5.34	0.64
5	4.85	0	0	90.53	5.92	3.55	5.33	0.66
6	4.73	0.76	0	89.14	7.19	2.90	5.33	0.68
7	4.61	1.64	0	87.62	8.53	2.21	5.32	0.69
8	4.48	2.63	0	85.93	9.97	1.47	5.31	0.71
9	4.36	3.80	0	84.04	11.56	0.60	5.29	0.73
10	4.23	4.72	0	81.31	13.97	0	5.28	0.74
11	4.11	5.31	0.23	73.62	20.84	0	5.22	0.75

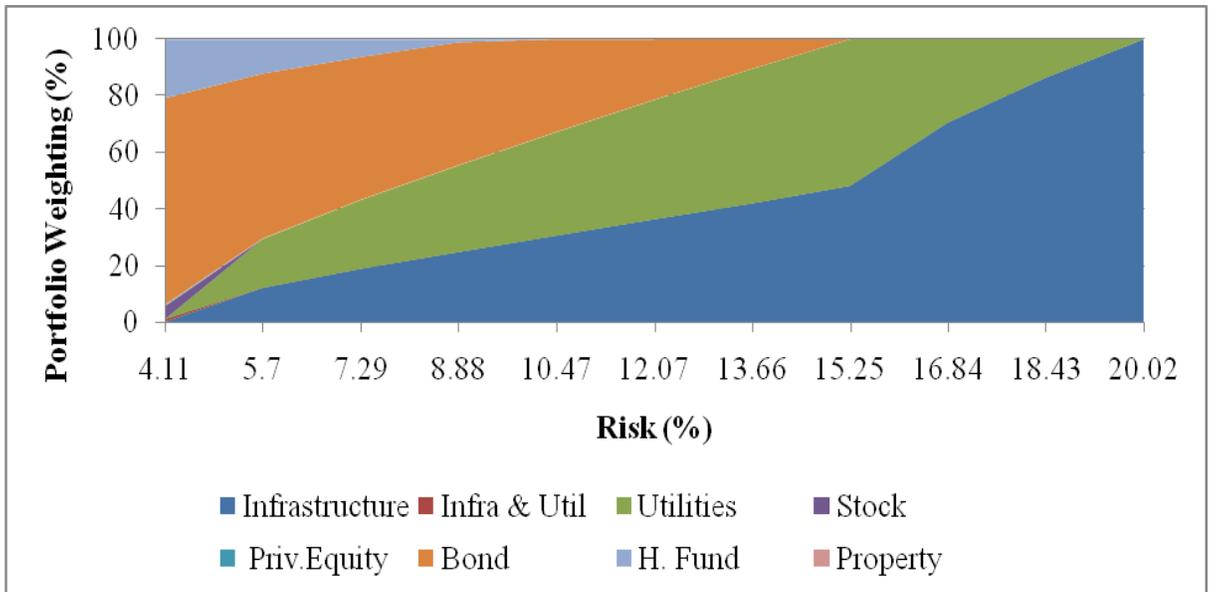
The addition of UK infrastructure, including infrastructure and utilities and utilities revealed a significant diversification benefit. This is clearly evident by the north-eastern movement of the efficient frontiers of the portfolio combinations including UK infrastructure compared to those without UK infrastructure. While infrastructure and utilities, stock, private equity and property were inactive, UK infrastructure was seen to play a key role within the mixed asset portfolio, the diversification benefit of including UK infrastructure and the other infrastructure asset classes (infrastructure and utilities and utilities) is apparent across the 8th to the 11th efficient sets with portfolio Sharpe indexes ranging between 0.77 and 0.92 higher than the optimal portfolio (0.75) without UK infrastructure. UK infrastructure is maximised within the portfolio at the tenth efficient set where 12.12% is allocated to UK infrastructure (Table 10). The other asset allocations in the optimal portfolio include 17.38% utilities, 58.36% bonds and 12.14% hedge funds. The inclusion of UK infrastructure, infrastructure and utilities and utilities reveals substantial diversification benefit of 32%.

In terms of portfolio weighting relative to risk, UK infrastructure saw higher allocations at higher risk levels (Figure 2). However the allocation to UK infrastructure reduces at a higher rate compared to the rate at which the portfolio risk reduces. For instance, at the optimal portfolio on the tenth efficient set, allocation to UK infrastructure was reducing at 35.74% compared to 21.81% risk reduction. In contrast, a higher allocation to bonds is mostly associated with lower risk levels, and is seen to disappear at risk level higher than 13.66%.

Table 10 Portfolio #3- With UK Infrastructures -Unconstrained

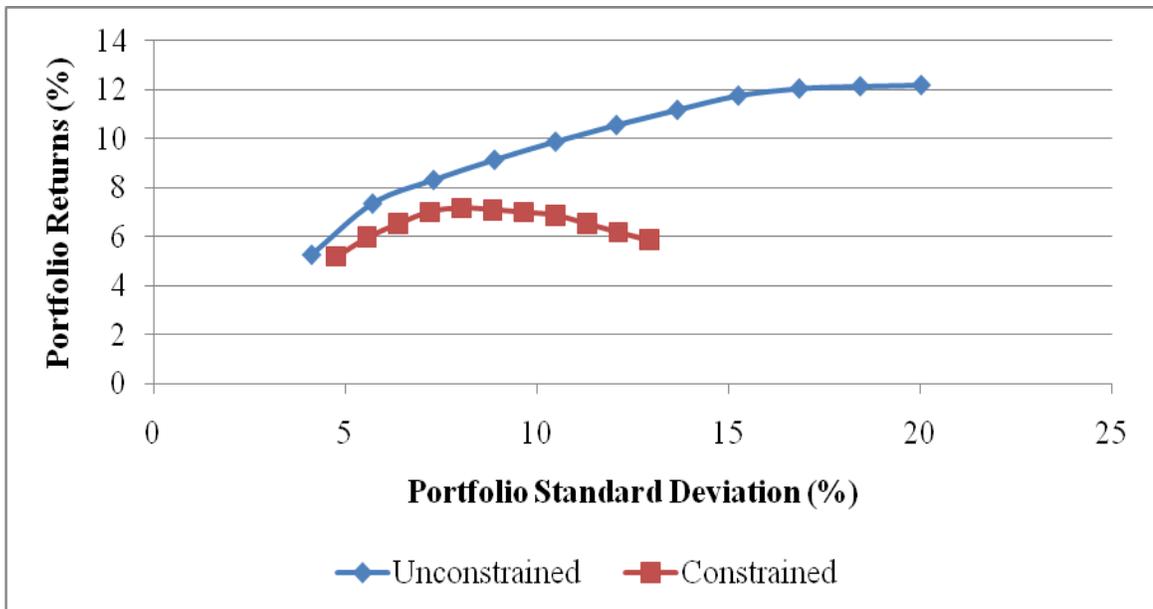
	MVP (%)	Infra	Infra and Util	Util	Stock	Priv. Eqty	Bonds	Hedge Fund	Pty	MRP (%)	PSI
1	20.02	100	0	0	0	0	0	0	0	12.2	0.50
2	18.43	86.44	0	13.56	0	0	0	0	0	12.15	0.54
3	16.84	70.60	0	29.40	0	0	0	0	0	12.06	0.59
4	15.25	48.17	0	51.83	0	0	0	0	0	11.77	0.63
5	13.66	41.96	0	47.60	0	0	10.44	0	0	11.19	0.66
6	12.07	36.36	0	42.25	0	0	21.39	0	0	10.57	0.70
7	10.47	30.61	0	36.62	0	0	32.76	0	0	9.89	0.74
8	8.88	24.76	0	30.66	0	0	43.51	1.07	0	9.15	0.79
9	7.29	18.85	0	24.36	0	0	50.50	6.30	0	8.33	0.85
10	5.70	12.12	0	17.38	0	0	58.36	12.14	0	7.37	0.92
11	4.11	0	1.05	0	4.60	0.31	73.19	20.85	0	5.28	0.77

Figure 2 UK Asset Allocation Relative to Risk-Unconstrained



The minimum risk in the constrained portfolio (4.74%) is marginally higher compared to 4.11% for the unconstrained (Figure 3). In contrast, the maximum return for the unconstrained portfolio (12.2%) is more than doubled that of the constrained portfolio (5.87%), however at different risk exposures, with the unconstrained posting higher portfolio risk (20.02%) than the constrained (12.94%).

Figure 3 Constrained and Unconstrained Efficient Frontiers of UK Infrastructure

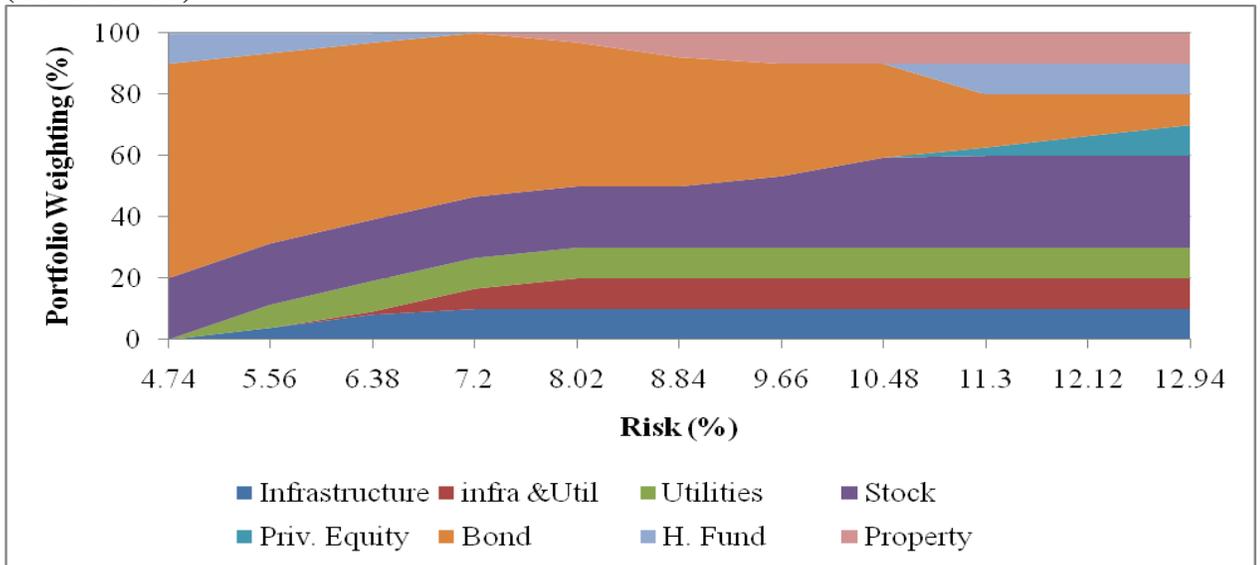


The portfolio profile assumes that all asset classes except stocks and bonds are held at an upper limit of 10%, while allocation to stocks is held at a lower bound of 20% and an upper bound of 30%, the rest is allocated to bonds. Although the diversification benefit of UK infrastructure is still clearly evident, the additional constraint is seen to have reduced the initial diversification benefit from 15% to 9%. However the most diversification gain is noticed along two different efficient sets with varying risk-return tradeoffs. For a risk averse investor, achieving a portfolio return of 5.97% at a risk level of 5.54% with a portfolio Sharpe ratio of 0.69 (Table 11) will be generally preferable. This is located along the tenth efficient set with portfolio combinations including 3.87% allocation to UK infrastructure, 7.52% utilities, 20% stocks, 6.52% hedge funds and the largest allocation of 62.08% to bonds.

Table 11 Portfolio #4- With UK Infrastructure (Constrained)

	MVP (%)	Infra	Infra and Util	Util	Stocks	Priv. Equity	Bonds	H. Fund	Pty	MRP (%)	PSI
1	12.94	10	10	10	30	10	10	10	10	5.87	0.29
2	12.12	10	10	10	30	6.45	13.55	10	10	6.2	0.34
3	11.3	10	10	10	30	2.68	17.32	10	10	6.54	0.39
4	10.48	10	10	10	29.38	0	30.62	0	10	6.88	0.45
5	9.66	10	10	10	23.33	0	36.67	0	10	7	0.50
6	8.84	10	10	10	20	0	42.15	0	5	7.1	0.56
7	8.02	10	10	10	20	0	46.97	0	3	7.17	0.63
8	7.2	10	6.64	10	20	0	53.36	0	0	7.02	0.68
9	6.38	8.18	0.98	10	20	0	57.73	3.11	0	6.54	0.69
10	5.56	3.87	0	7.52	20	0	62.08	6.52	0	5.98	0.69
11	4.74	0	0	0	20	0	70	10	0	5.2	0.65

Figure 4 UK Infrastructures and Other Assets' Allocation Relative to Risk- (Constrained)



Achieving a similar diversification benefit is possible at a higher risk level of 6.38% though offset by a higher portfolio return of 6.54% located along the ninth efficient set. At this point, a higher portion of 8.18% is allocated to UK infrastructure and less than one percent allocated to infrastructure and utilities (0.98%), a maximum allocation of 10% to utilities, stocks are held at the lower bound of 20%, while hedge fund and bonds were allocated 3.11% and 57.73% respectively.

Allocations to UK infrastructure were consistent at the maximum limit of 10% up to the 8th efficient set before dropping to 8.18% and 3.7% at portfolio risk levels of 6.38% and 5.56% respectively (Figure 4). While none of the infrastructure asset classes saw significant allocation at the minimum risk portfolio, investment in utilities (7.52%) was highest at the second lowest risk level of 5.56%. The portfolio weighting relative to risk shows higher allocations to bonds particularly at the lower risk levels, the maximum allocation of 70% to bonds was at the minimum risk portfolio (4.74%), with the rest allocated between stocks (20%) and hedge funds (10%).

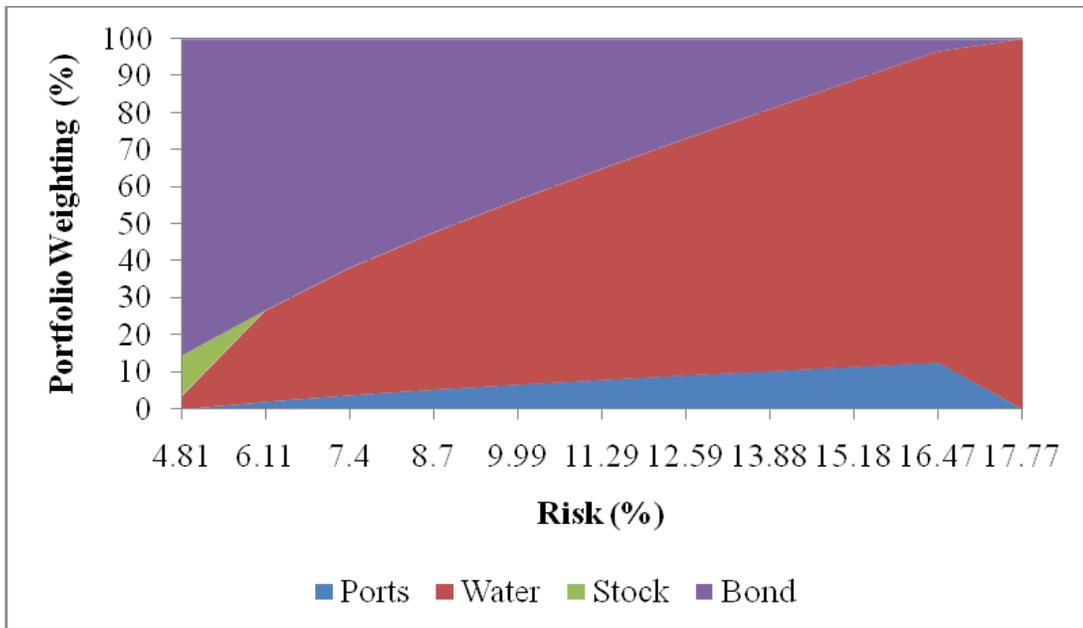
The outstanding performance of specific UK infrastructure sub-sectors is reflected in the increased diversification benefit seen in the optimal portfolio on the tenth efficient set (Table 12). To be consistent with the previous individual performance benchmark (bonds

Sharpe ratio = 0.60), the diversification benefit is seen to have been significantly enhanced to 41% given a Sharpe ratio of 1.01 at the optimal portfolio level.

Table 12 Asset Allocation Including UK Infrastructure Sub-Sectors

	MVP (%)	Ports	Water	Stock	Bonds	MRP (%)	PSI
1	17.77	0	100	0	0	15.54	0.75
2	16.47	12.56	84.16	0	3.28	15.14	0.79
3	15.18	11.44	77.51	0	11.05	14.45	0.81
4	13.88	10.26	70.82	0	18.92	13.73	0.84
5	12.59	9.12	63.98	0	26.90	12.99	0.86
6	11.29	7.89	57.06	0	35.06	12.21	0.89
7	9.99	6.61	49.92	0	43.47	11.39	0.93
8	8.70	5.29	42.43	0	52.28	10.5	0.96
9	7.40	3.77	34.35	0	61.88	9.51	1.00
10	6.11	2.03	24.60	0	73.37	8.3	1.01
11	4.81	0	3.36	10.95	85.69	5.69	0.74

Figure 5 UK Ports, Water, stock and Bonds Allocation Relative to Risk



Asset allocations at the optimal portfolio revealed higher investment in UK water (24.60%) compared to 2.03% in ports, and the remaining 73.37% allocated to bonds. Equally significant is the portfolio weighting relative to risk, which reveals the dominance of UK water ranging between 100% at a portfolio risk of 17.77% to 3.36% at portfolio risk of 4.81% (Figure 5). While a marginal allocation to UK ports is seen to vary between 12.56% (at portfolio risk of 16.47%) to 2.03% (at portfolio risk of 6.11%), higher allocations to bonds is seen towards the lower end of the efficient sets up to the maximum of 85.69% at the minimum risk portfolio (4.81%).

7. Conclusion and Summary of Chapter Seven

The paper reveals the increasingly significant position of UK infrastructure within a mixed asset portfolio and its emergence as a unique asset class. The paper explored the performance of UK listed infrastructure investment on a risk-adjusted basis over a ten year period (2001-2010) using monthly return indices obtained from Thomson Reuters Database. The ten year timeframe was further classified into three time periods; the pre-GFC, the GFC and the post-GFC in order to fully assess the impact of the global financial crisis on UK infrastructure investment relative to other major asset classes. Over the ten year time frame, investments in UK listed infrastructure show a robust performance despite the global financial crisis, hence, the study is supportive of the argument that the inclusion of UK listed infrastructure in a mixed asset portfolio enhances investment performance, evidenced by the north-eastern expansion of the efficient frontiers. The findings are consistent with previous studies (RREEF 2008, Newell et al 2009, Finkenzeller et al 2010, Newell et al 2011 and Singhal et al 2011) which hitherto had focused on the Australian, China, India and US infrastructures.

The performance results show that UK infrastructure produced better risk-return trade-offs than those of UK property, private equity, hedge funds and UK stocks. Overall, for the ten year period, UK Water was the best performing asset class outperforming all other asset classes having the highest Sharpe ratio of 0.75. The sub-period analysis facilitates a fuller understanding of UK infrastructure performance across varying economic conditions, with the benefit of enhancing investment decision making predominantly in periods of adverse

financial climates. However, the GFC period, characterised by contracted credit facilities adversely affected UK infrastructure investment with the majority of the asset classes having negative annualised returns and relatively high volatilities. Caution becomes relevant for investors particular during period of unique economic conditions and a more reflective appreciation of infrastructure performance and correlation with other asset classes is a necessary condition for a sustainable portfolio allocation.

Notwithstanding the downturn, infrastructure was seen to outperform other asset classes. Important findings from the paper show that despite the GFC, UK infrastructure saw superior performance, with positive annualised returns outperforming other UK assets except UK bonds. Apart from UK bonds investments with the highest performance Sharpe ratios of 0.92 respectively, UK infrastructure was the only asset class with positive performance during the global financial crisis period with Sharpe ratios of 0.09. This potentially displays the resilience of infrastructure against the vagaries of economic downturns.

Using the monthly return indices over the ten year period, UK listed infrastructure investment was found to play a consistently significant role in the optimality of mixed-asset portfolios. However, the diversification benefits were more return enhancing than risk reducing, offering investors a platform for matching investment objectives with expectations resulting from a better understanding of the characteristics of UK listed infrastructure investments.

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