A Publication of the EDHEC Infrastructure Institute-Singapore

Searching for a Listed Infrastructure Asset Class

Mean-variance spanning tests of 22 listed infrastructure proxies

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This study presents the author's views and conclusions which are not necessarily those of EDHEC Business School.

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Executive Summary

Executive Summary

In this paper, we ask the question: does focusing on **listed infrastructure stocks** create diversification benefits previously unavailable to large investors already active in public markets?

This question arises from what we call the "infrastructure investment narrative" (Blanc-Brude, 2013), a set of investment beliefs commonly held by investors about the investment characteristics of infrastructure assets.

In this narrative, the "infrastructure asset class" is less exposed to the business cycle because of the low price-elasticity of infrastructure services. Furthermore, the value of these investment is expected to be mostly determined by income streams extending far into the future, and should thus be less impacted by current events.

According to this intuition, **listed infrastructure** may provide diversification benefits to investors since they are expected to exhibit low return covariance with other financial assets. In other words, listed infrastructure is expected to exhibit sufficiently unique characteristics to be considered an "asset class" in its own right.

Empirically, there are at least three reasons why this view requires further examination:

1. Most existing research on infrastructure has used public equity markets to infer findings for the whole infrastructure investment universe, but robust and conclusive evidence is not forthcoming in existing papers;
2. Index providers have created dedicated indices focusing on this theme and a number of active managers propose to invest in "listed infrastructure" arguing that it does indeed constitute a unique asset class;
3. Listed infrastructure stocks are often used by investors to proxy investments in privately held (unlisted) infrastructure equity, but the adequacy of such proxies remains untested.

The existence of a distinctive *listed infrastructure effect* in investors' portfolio would support these views. In the negative, if this effect cannot be found, there is little to expect from listed infrastructure equity from an asset allocation (risk/reward optimisation) perspective and maybe even less to learn from public markets about the expected performance of unlisted infrastructure investments.

Testing 22 proxies of listed infrastructure

We test the impact of adding 22 different proxies of "listed infrastructure" to the portfolio of a well-diversified investor using mean-variance spanning tests. We focus on three definitions of "listed infrastructure" as an asset selection scheme:

1. A "naïve", rule-based filtering of stocks based on industrial sector classifications and percentage income generated from

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pre-defined infrastructure sectors (nine proxies);
2. Existing listed infrastructure indices designed and maintained by index providers (twelve proxies);
3. A basket of stocks offering a pure exposure to several hundred underlying projects that correspond to a well-known form of infrastructure investment defined – in contrast with the two previous cases – in terms of long-term public-private contracts, not industrial sectors (one proxy).

Employing the mean-variance spanning tests originally described by Huberman and Kandel (1987) and Kan and Zhou (2012), we test the diversification benefits of these proxies of the listed infrastructure effect.

There is no listed infrastructure asset class

Stylised findings include:

1. Our 22 tests of listed infrastructure reveal little to no robust evidence of a "listed infrastructure asset class" that was not already spanned by a combination of capital market instruments and alternatives, or by a factor-based asset allocation;
2. The majority of test portfolios that improve the mean-variance efficient frontier before the GFC fail to repeat this feat post-GFC. There is no evidence of persistent diversification benefits;
3. Of the 22 test portfolios used, only four manage to improve on a typical asset allocation defined either by traditional asset class or by factor exposure *after* the GFC and only one is not already spanned both pre- and post-GFC;
4. Building baskets of stocks on the basis of their SIC code and sector-derived income fails to generate a convincing exposure to a new asset class.
5. Hence, benchmarking unlisted infrastructure investments with thematic (industry-based) stock indices is unlikely to be very helpful from a pure asset allocation perspective i.e. the latter do not exhibit a risk/return trade-off or *betas* that large investors did not have access to already.

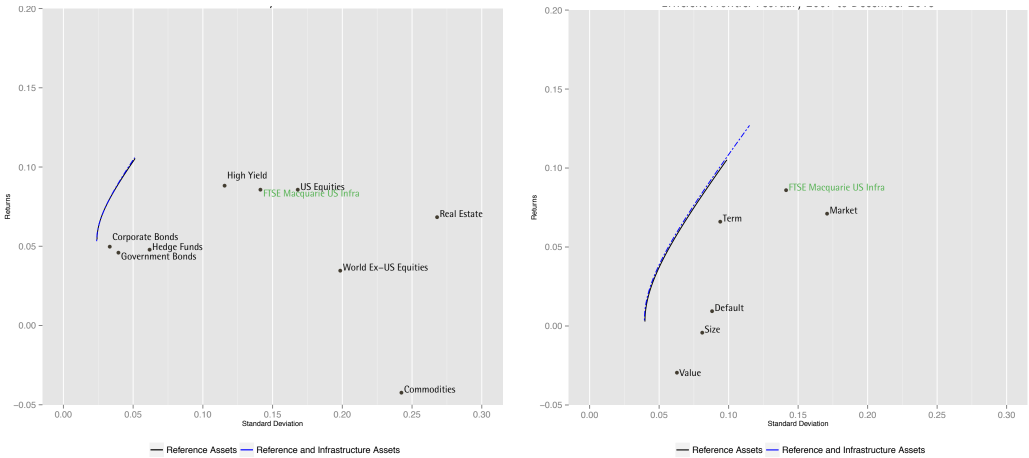
Overall, we do not find *persistent* evidence to support the claims that listed infrastructure is an asset class. In other words, any "listed infrastructure" effect was already spanned by a combination of capital market instruments over the past 15 years in Global, US and UK markets.

Defining infrastructure investments as a series of industrial sectors and/or tangible assets is fundamentally misleading. We find that such asset selection schemes do not create diversification benefits, whether reference portfolios are structured by traditional asset classes or factor exposures.

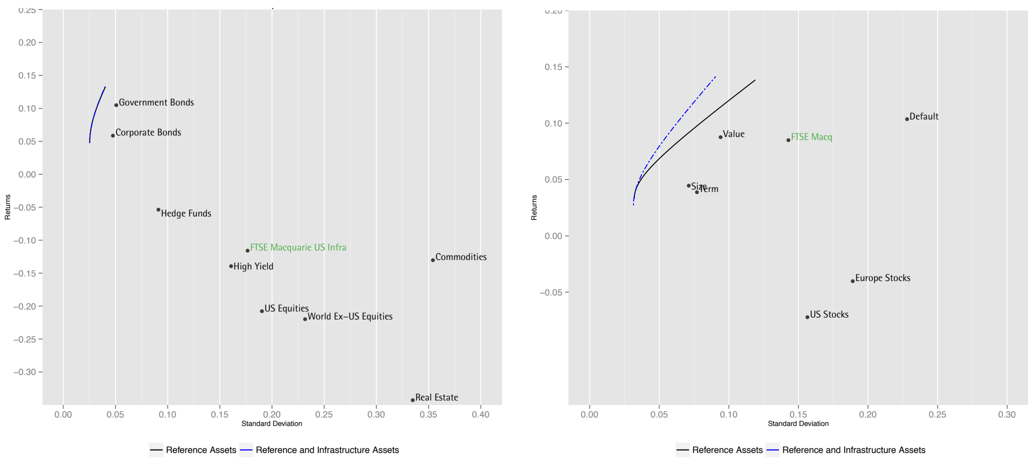
We conclude that what is typically referred to as **listed infrastructure**, defined by SIC code and industrial sector, **is not an asset class or a unique combination of market factors**, but instead cannot be persistently distinguished from existing exposures in

Figure 1: Illustration of the difference tests of mean-variance spanning of the FTSE Macquarie USA Infrastructure Index

(a) 2000-2014, asset class and factor-based reference



(b) 2000-2008, asset class and factor-based reference



(c) 2009-2014, asset class and factor-based reference

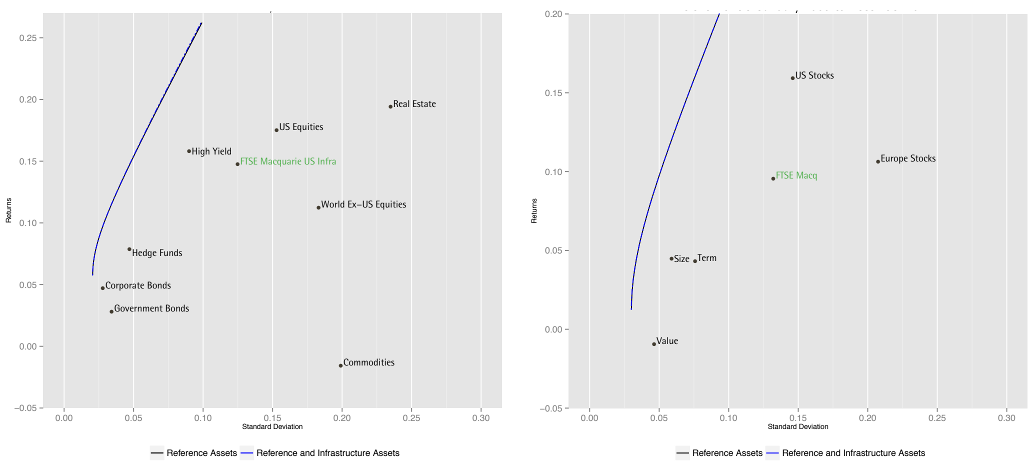


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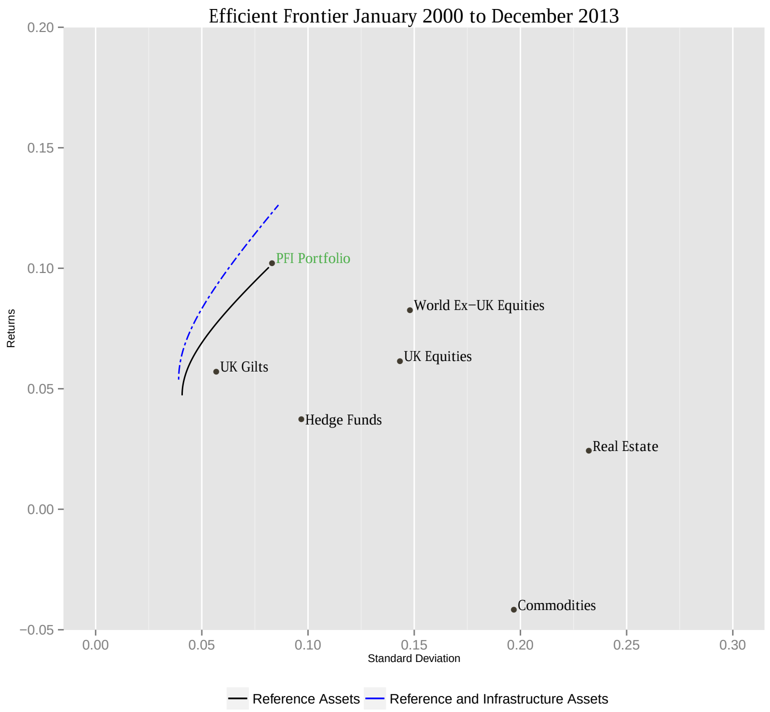
Figure 2: Mean-Variance Frontier of total returns PFI portfolio and reference portfolio, 2000-2014



investors' portfolios, and that expecting the emergence of a new or unique "infrastructure asset class" by focusing on public equities selected on the basis of industrial sectors is unlikely to be very useful for investors.

Figure 1 provides an illustration of these results in the case of the FTSE Macquarie Listed Infrastructure Index for the U.S. market.

Thus, asset owners and managers who use the common "listed infrastructure" proxies to benchmark private infrastructure investments are either misrepresenting (probably over-estimating) the beta of private infrastructure, and usually have to include various "add-ons" to such approaches, making them completely *ad hoc* and unscientific.

Defining infrastructure differently

Our tests also tentatively suggest a more promising avenue to "find infrastructure" in the public equity space: focusing on underlying contractual or governance structures that tend to maximise dividend payout and pay dividends with great regularity, such as the public-private partnerships (PPPs) or master limited partnerships (MLPs) models, we find that the mean-variance frontier of a reference investor *can* be improved.

The answer to our initial question partly depends on how "infrastructure" is defined

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and understood as an asset selection scheme.

Under our third definition of infrastructure, which focuses on the relationship-specific and contractual nature of the infrastructure business, we find that listed infrastructure may help identify exposures that have at least the potential to persistently improve portfolio diversification on a total return basis, as figure 6 illustrates. This effect is driven by the regularity and the size of dividend payouts compared to other corporations, infrastructure or not.

What determines this ability to deliver regular and high dividend payouts is the contractual and governance structure of the underlying businesses, not their belonging to a given industrial sector. Bundles of PPP project companies or MLPs behave differently than regular corporations i.e. their ability to retain and control the free cash flow of the firm is limited and they tend to make large equity payouts. In the case if PPP firms, as Blanc-Brude et al. (2016) show, they also pay dividends with much greater probability than other firms.

Going beyond sector exposures and focusing on the underlying business model of the firm is more likely to reveal a unique combination of underlying risk factors.

However, it must be noted that the relatively low aggregate market capitalisation of listed entities offering a "clean" exposure to infrastructure "business models" as opposed to "infrastructure corporates" may limit the ability of investors to enjoy these potential benefits unless the far larger *unlisted* infrastructure fund universe has similar characteristics.

Future work by EDHEC*infra* aims to answer these questions in the years to come.

1. Introduction

1. Introduction

In this paper, we ask the question: does focusing on listed infrastructure stocks create diversification benefits previously unavailable to large investors already active in public markets?

This question arises from what we call the "infrastructure investment narrative" (Blanc-Brude, 2013), a set of investment beliefs commonly held by investors about the investment characteristics of infrastructure assets.

In this narrative, the "infrastructure asset class" is less exposed to the business cycle because of the low price-elasticity of infrastructure services. Furthermore, the value of these investment is expected to be mostly determined by income streams extending far into the future, and should thus be less impacted by current events.

According to this intuition, infrastructure investments may provide diversification benefits to investors since they are expected to exhibit low return covariance with other financial assets, as well as a degree of downside protection. In other words, infrastructure investments are expected to exhibit sufficiently unique characteristics to be considered an "asset class" in its own right.

Empirically, there are at least three reasons why this view requires further examination:

1. Most existing research on infrastructure has used public equity markets to infer findings for the whole infrastructure investment universe, but robust and conclusive evidence is not forthcoming in existing papers;
2. Index providers have created dedicated indices focusing on this theme and a number of active managers propose to invest in "listed infrastructure" arguing that it does indeed constitute an asset class in its own right, worthy of an individual allocation;
3. Listed infrastructure stocks are often used by investors to proxy investments in privately-held (unlisted) infrastructure but the adequacy of such proxies remains untested.

The existence of a distinctive *listed infrastructure effect* in investors' portfolio would support these views. In the negative, if this effect cannot be found, there is little to expect from listed infrastructure equity from an asset allocation (risk/reward optimisation) perspective and maybe even less to learn from public markets about the expected performance of unlisted infrastructure investments.

We test the impact of adding 22 different proxies of public infrastructure stocks to the portfolio of a well-diversified investor using mean-variance spanning tests. We focus on three definitions of "listed infrastructure" as an asset selection scheme:

1. A "naïve", rule-based filtering of stocks based on industrial sector classifications and percentage income generated from pre-defined infrastructure sectors (nine proxies);

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2. Existing listed infrastructure indices designed and maintained by index providers (twelve proxies);
3. A basket of stocks offering a pure exposure to several hundred underlying projects that correspond to a well-known form of infrastructure investment defined – in contrast with the two previous cases – in terms of long-term public-private contracts, not industrial sectors (one proxy).

Overall, we do not find *persistent* evidence to support the claims that listed infrastructure provides diversification benefits. In other words, any "listed infrastructure" effect was already spanned by a combination of capital market instruments over the past 15 years in Global, US and UK markets.

We show that listed infrastructure, as it is traditionally defined (by their SIC code and industrial sector), is not an asset class or a unique combination of market factors, but instead cannot be distinguished from existing exposures in investors' portfolios.

We also find that the answer to our question partly depends on how "infrastructure" is defined and understood as an asset selection scheme.

Hence, under our third definition of infrastructure, which focuses on the relationship-specific and contractual nature of the infrastructure business, we find that listed infrastructure may help identify exposures that have at least the potential to persistently improve portfolio diversification. In other words, going beyond sector exposures and focusing on the underlying business model of the firm is more likely to reveal a unique combination of underlying risk factors.

The rest of this paper is structured as follows: section 2 briefly reviews existing research on the performance of listed infrastructure. Section 3 details our approach, while sections 4 and 5 present our choice of methodology and data, respectively. The results of the analysis are reported in section 6. Finally, Section 7 discusses our findings and their implications to better define and benchmark infrastructure equity investments.

2. Literature Review

2. Literature Review

In Fabozzi and Markowitz (2011, p. 16), asset classes are defined as homogenous investments with comparable characteristics, driven by similar factors, including a common legal or regulatory structure, thus correlating highly with each other.

As a direct result of this definition, the combination of two or more asset classes can be expected to create diversification benefits due to the limited return *covariance* of each group of assets.

The question of whether listed infrastructure is an asset class and a good proxy of a broader universe of privately-held infrastructure equity has been discussed in previous research. The approach taken in the literature has been to define infrastructure in terms of industrial categories: roads and airports can seem rather alike as businesses when compared with automotive factories or financial services. Hence, following the definition given above, they can expected to form a relatively homogeneous group of stocks – a potential asset class – compared to other segments of the economy.

Existing studies can be organised in two groups. First, papers applying rule-based stock selection schemes focusing on what is traditionally understood as "infrastructure" i.e. a collection of industrial sectors. Second, papers that employ listed infrastructure indices created by a number of index providers.

2.1 Rule-based listed infrastructure portfolios

The first group of papers simply examines those stocks that are classified under a set list of infrastructure *activities* and derive a certain proportion of their income from these activities (see Newell and Peng (2007), Finkenzeller et al. (2010), Newell and Peng (2008), Newell et al. (2009), Rothballer and Kaserer (2012a) and Bitsch (2012)).

The findings from these studies suggest considerable heterogeneity in "listed infrastructure". Newell and Peng (2007) report that listed Australian infrastructure exhibits **higher returns, but also higher volatility** than equity markets. They find higher Sharpe ratios than the market and low but growing correlations over time with market returns. Finkenzeller et al. (2010) find similar results.

The work of Newell and Peng (2008) finds that in the U.S., **infrastructure (ex-utilities) under-performs stocks** and bonds over the period from 2000 to 2006, while utilities outperform the market. Rothballer and Kaserer (2012a) find that infrastructure stocks exhibit **lower market risk than equities in general but not lower total risk** i.e. they find high idiosyncratic volatility.

They also report significant heterogeneity in the risk profiles of different infrastructure sectors with an average beta of 0.68 but with variation between sectors. For the utility, transport and telecom companies, the average betas were 0.50, 0.73 and 1.09,

2. Literature Review

respectively.[1] Bitsch (2012) finds that infrastructure vehicles are priced using a high risk premium in part because of – he argue – complex and opaque financial structuring, information asymmetries with managers, regulatory and political risks.

These findings are in line with the results of several industry studies suggesting that the volatility of infrastructure indices is on par with equities and real estate, but that market correlation is relatively low (Colonial First State Asset Management, 2009; RREEF 2007).

The conclusions from this strand of literature are limited. "Infrastructure" stocks are founds to have higher Sharpe ratios in some cases but the **statistical significance of this effect is never tested**. Overall, rule-based infrastructure stocks selection schemes lead to either anecdotal (small sample) or heterogenous results, which do not support the notion of an independent asset class.

2.2 *Ad hoc* listed infrastructure indices

A second group of studies uses infrastructure indices created by index providers such as Dow Jones, FTSE, MSCI and S&P, as well as financial institutions such as Brookfield, Macquarie or UBS. These indices are not fundamentally different from the approach described above.

They use asset selection schemes based on slightly different industrial definitions of what qualifies as "infrastructure" and apply a market-capitalisation weighing scheme. They are *ad hoc* as opposed to rule-based because index providers pick and choose which stocks should be included in each infrastructure index.

Using such indices, Bird et al. (2014) and Bianchi et al. (2014) find that infrastructure exhibits similar returns, correlations and tail-risks than the market, with a marginally higher Sharpe ratio, driven by what could be described as a 'utility tilt'.

Other recent studies on the performance of infrastructure indices by Peng and Newell (2007), Finkenzeller et al. (2010), Dechant and Finkenzeller (2013) and Oyedele et al. (2014) also report potential diversification benefits, but none examine whether these are statistically or economically significant. For example, Peng and Newell (2007) and Oyedele et al. (2014) compare Sharpe ratios but provide **no statistical tests to support their conclusions**.

Idzorek and Armstrong (2009) provide the only study of the role of listed infrastructure in a portfolio context. The authors create an infrastructure index by combining existing industry indices. Using three versions of their composite index (low, medium and high utilities), and consistent with previous papers, they report that over the 1990-2007 period, infrastructure returns were similar to that of U.S. equities but with slightly less risk. Finally, using the CAPM to create a forward-looking model of expected returns including an infrastructure

1 - Using the same sample than Rothballer and Kaserer (2012a), Rödel and Rothballer (2012), examine the inflation hedging ability of infrastructure.
They find no evidence to suggest infrastructure exhibits a greater ability to hedge inflation risks than listed equities. Even restricting their sample to firms with assumed strong monopoly characteristics does not yield a statistically significant result.

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allocation, Idzorek and Armstrong (2009) find that adding infrastructure does not lead to a meaningful improvement of the efficient frontier, but again provide no statistical test of the robustness of their results.

2.3 Limitations of existing research

The existing literature has not examined whether different types of listed infrastructure investments are not already spanned in the portfolio of a typical investor. As a result, it remains unclear whether a focus on infrastructure-related stocks can create additional diversification benefits for investors. Nor is it clear whether "infrastructure" is a new combination of investment factor exposures.

In the rest of this paper, we test statistically whether infrastructure stocks, selected according to their industrial classification, provide diversification benefits to investors. Furthermore, following the argument in Blanc-Brude (2013), we examine a different definition of infrastructure focussing on the "business model" as determined by the role of long-term contracts in infrastructure projects. Next, we describe our approach in more detail.

3. Approach

3. Approach

3.1 Testing three definitions of listed infrastructure

We propose to test the portfolio characteristics of listed infrastructure equity under the three different definitions of what constitutes "infrastructure" proposed in section 1.

These first two proxies – a "naïve", rule-based filtering of stocks based on industrial sector classifications and listed infrastructure indices maintained by index providers – focus on the "real" characteristics of the relevant capital projects and bundles together assets that may all be related to large structures of steel and concrete, but may also have radically different risk profiles from an investment view point.

Hence, we also identify stocks which happen to create a useful *natural experiment*[2]: a basket of stocks offering a pure exposure to projects that correspond to a specific long-term contract but not to any specific industrial sectors.

2 - i.e. Experimental and control conditions are determined by factors outside our control

Instead, this basket captures a specific infrastructure "business model": these are the publicly traded shares of investment vehicles that are solely involved in buying and holding the equity of infrastructure projects engaged in PFI (Private Finance Initiative) projects in the UK and, to a lesser extent, their equivalents in Canada, France and the rest of the OECD.

PFI projects consists of dedicated project firms entering into long-term contracts with the public sector to build, maintain and operate public infrastructure facilities according to a pre-agreed service output specification. As long as these firms deliver the projects and associated services for which they have been mandated, on time and according to specifications, the public sector is committed to pay a monthly or quarterly income to the firm according to a pre-agreed schedule for multiple decades. In the UK, the long-term contract between the public and private parties also stipulated that this "availability payment" is also adjusted to reflect changes in the retail price index (RPI). Each project company is a special purpose vehicle created solely to deliver an infrastructure project and financed on a non-recourse basis with sponsor equity, shareholder loans and senior debt.

The firms we identify are listed on the London Stock Exchange, buy and hold the equity and shareholder loans (quasi-equity) of hundreds of these PFI project companies and subsequently distribute dividends to they shareholders. They are, in effect, a listed basket of PFI equity (with no additional leverage) and, as such represent a pure proxy of one model of private infrastructure investment. We provide a full list of the underlying firms in the appendix.

We expect the cash flows of these firms to be highly predictable, uncorrelated with markets and the business cycle, albeit highly correlated with the UK RPI index. In other words, we expect to see some evidence of the "infrastructure investment narrative"

3. Approach

discussed earlier, that has so far eluded studies of infrastructure stocks defined by their SIC code.

3.2 Testing asset classes or factors?

Using these three alternative approaches to define infrastructure investment, we use the mean-variance spanning tests designed by Huberman and Kandel (1987) and Kan and Zhou (2012) to determine whether adding a listed infrastructure bucket to an existing investment portfolio significantly increases diversification opportunities.

In the affirmative, this result implies a degree of "asset class-ness" of infrastructure stocks since their addition to a reference portfolio effectively shifts the mean-variance efficient frontier (to the left) and creates new diversification opportunities for investors. Furthermore, we define the reference portfolio used to test the mean-variance spanning properties of listed infrastructure either in terms of traditional asset classes and of investment factors.

Indeed, the notion of asset class is losing its relevance in investment management since the financial crisis of 2008-11, when existing asset class-based allocations failed to prove well diversified (see for example Ilmanen and Kizer, 2012).

Factor-based asset allocations aim to identify those persistent dimensions of financial assets that best explain (and predict) their performance instead of assuming that assets belong to distinctive categories because they have different names.[3]

Thus, we include both a traditional asset allocation based on asset classes and a factor based allocation to test whether listed infrastructure is indeed an asset class or, alternatively, a unique combination of investment factors.

3.3 Testing persistence

Finally, we test the existence of a *persistent* effect of listed infrastructure on a reference portfolio by splitting the observation period in two, from 2000 to 2008 and from 2008 to 2014, to test for the impact of the 2008 reversal of the credit cycle a.k.a. the Global Financial Crisis (GFC) and the distorting role excessive leverage may have played in the first period. In section 6, we report results for the whole sample period, as well as for two sub-sample periods denoted as pre- and post-GFC periods.

In the case of the PFI portfolio, data starts in 2006 and so we also split the sample in 2011, which marks the time of the Eurozone debt crisis and launch of quantitative easing policies by the Bank of England.

In the next section, we discuss the mean-variance spanning methodology used in the remaining sections of this paper.

3 - Such factors include the Fama and French (1992) Size and Value premiums, the Term and Default premiums (Fama and French, 1993) and the Momentum premium identified by Jegadeesh and Titman (1993). Bender et al. (2010) shows that these premiums are uncorrelated with each other, increase returns and reduce portfolio volatility over traditional asset class allocations. Likewise, when comparing the diversification benefits of factor-based allocations to alternative assets, Bird et al. (2013) finds that factor approaches tend to outperform alternative asset classes. For recent and in-depth analyses of factor investing, see Amenc et al. (2014).

4. Methodology

4. Methodology

In a mean-variance framework, the question of whether listed infrastructure provides diversification benefits is equivalent to asking whether investors are able to improve their optimal mean-variance frontier by including infrastructure stocks to an existing portfolio.

This question can be answered using the mean-variance spanning test described by Huberman and Kandel (1987), which tests whether the efficient frontier is improved **up to given level of statistical significance** when including new assets.

If the mean-variance frontier, inclusive of the new assets, coincides with that already produced by the reference assets, the new assets can be considered to be already spanned by the existing portfolio i.e. no new diversification benefit is created. Conversely, if the existing mean-variance frontier is shifted to the left in the mean/variance plane, by the addition of the new asset, investors have improved their investment opportunity set.

This approach has been used to examine the diversification benefits in different asset classes. For instance, Petrella (2005) and Eun et al. (2008) employ this methodology to examine the diversification benefits of small cap stocks. Likewise, Kroencke and Schindler (2012) examines the benefits of international diversification in real estate using mean-variance spanning, while Chen et al. (2011) examines the diversification benefits of volatility. However, to date it has not been used in the literature on listed infrastructure.

Mean-variance spanning is a regression based test that assumes that there are K reference assets as well as N test assets. In Huberman and Kandel (1987), there is a linear relationship between test and reference assets so that:

$$R_{2t} = \alpha + \beta R_{1t} + \varepsilon_t \tag{4.1}$$

with $t = 1, \ldots T$ periods and R_1 represents a $T \times K$ matrix of excess realised returns of the K benchmark assets. R_2 represents a $T \times N$ matrix of realised excess returns of the N test assets. β is a $K \times N$ matrix of regression factor loadings and ε is a vector of the regression error terms.

The null hypothesis is that existing assets already span the new assets. This implies that the α of the regression in equation 4.1 is equal to zero, whilst the sum of the βs equals one. As a result, the null hypothesis assumes that a combination of the existing benchmark assets is capable of replicating the returns of the test assets with a lower variance.

Kan and Zhou (2012) describes the null hypothesis as :

$$H_{0S} = \alpha = 0_N, \delta = 1_N - \beta 1_K = 0_N \tag{4.2}$$

Where α_N is an N-vector of regression intercept coefficients and β is the matrix of factor loadings.

4. Methodology

As this analysis is only examining the addition of one test asset at a time the test statistic is given by: [4]

$$HK = \left(\frac{1}{V} - 1\right)\left(\frac{T - K - 1}{2}\right) \qquad (4.3)$$

where V is the ratio of the determinant of the maximum likelihood estimator of the error co-variance matrix of the model assuming that there is no spanning of the efficient frontier (otherwise known as the unrestricted model) to that of the determinant of the maximum likelihood estimator of the model that assumes spanning occurs (known as the restricted model).

T is the number of return observations, K is the number of benchmark assets included in the study. The HK variable is a Wald-test statistic and follows an F-distribution with $(2, T - K - 1)$ degrees of freedom.

In addition to the Huberman and Kandel (1987) test, Kan and Zhou (2012) develop a two-stage test to examine whether the rejection of the Huberman and Kandel (1987) null hypothesis is due to differences in the tangency or the Global Minimum Variance as a result of the addition of new assets.

The first step of the Kan and Zhou (2012) test examines whether $\alpha = 0_N$. If the null is rejected at this stage, the two tangency portfolios comprising of the benchmark assets, and the benchmark and new assets, respectively, are statistically different.

The second stage of the Kan and Zhou (2012) test examines whether $\delta = 0_N$ conditional on $\alpha = 0_N$. If the null hypothesis is rejected, the Global Minimum Variance of the test portfolio and the benchmark portfolios are statistically different (see also Chen et al., 2011, for a discussion).

In this paper, we incorporate both the Huberman and Kandel (1987) and Kan and Zhou (2012) tests to examine the ability of infrastructure to provide portfolio diversification benefits. [5]

Next, we describe the data used in this study.

4 - Kan and Zhou (2012) state that if $\mathbf{N} \geq 2$ then the appropriate formation of the test statistic is given as $\mathrm{HK} = \left(\frac{1}{V^{\frac{1}{2}}} - 1\right)\left(\frac{T - K - 1}{2}\right)$.

5 - As another robustness check we employ the Gibbons et al. (1989) test of portfolio efficiency. The results, are similar to the mean-variance span test results presented in this paper. The results are available upon request.

5. Data

5. Data

This section describes the datasets used to build test portfolios of listed infrastructure and reference portfolios to apply the mean-variance spanning methodology described previously.

Sections 5.1, 5.2, and 5.3 describe listed infrastructure proxies designed with sector-based asset selection rules, index-provider data, and the PFI portfolio, respectively. Section 5.4 describes the reference portfolios.

5.1 Test Assets - Listed infrastructure companies

5.1.1 Asset selection

The first asset selection scheme represents the "naïve" definition of infrastructure equity investment, and follows the methodology described by Rothballer and Kaserer (2012b) following broad industry definitions to determine infrastructure-related stocks [6].

5,757 possible securities listed in global markets are thus identified as infrastructure-related. Next, only stocks for which the majority of the revenue was obtained from sectors corresponding to infrastructure activities are kept in the sample.

A minimum market capitalisation of USD500 Million is also required to be included in the sample. This yields 1,290 firms with at least 50% of their income from infrastructure activities The minimum revenue by infrastructure type is reported by SIC or GIC code by Worldscope. This is a crude measure as it relies on the continuous updating of the revenue codes by Worldscope, as well as assuming that GIC or SIC codes represent infrastructure activities.

Setting a minimum infrastructure sector revenue threshold to 75% and 90%, yields 650 and 554 stocks, respectively.

U.S. dollar price and total returns are sourced from Datastream using the methodology described in Ince and Porter (2006).[7] The firms thus identified comprise at most 12%, 7% and 6.5% of the of the MSCI World market value as at 31 December 2014, for the 50%, 75% and 90% infrastructure revenue thresholds, respectively.

5.1.2 Descriptive Statistics

For market-cap weighted portfolios of infrastructure stocks defined according to the industry-based scheme described above, we report annualised returns, standard deviation and Sharpe ratios and the maximum drawdown ratios for the period 2000-2014 for price and total returns. in table 1.

It is useful to note that the reference market index should not be difficult to beat. The MSCI World index is a free float adjusted market capitalisation weighted index comprising of 1,631 mid and large capitalisation stocks across 23 developed country equity markets. MSCI states that the index comprises 85% of the free-float adjusted market capitalisation

6 - The SIC and GIC codes used to identify infrastructure are available upon request.

7 - Extreme monthly returns are identified following Ince and Porter (2006) and set to a missing value. Ince and Porter (2006) sets an arbitary cut off of 300% for extreme monthly returns. If R_1 or R_{t-1} is greater than 300% and $(1+R_1)/(1+R_{t-1})-1$ is less than 50% then R_1 or R_{t-1} are set to missing. Furthermore, following Rothballer and Kaserer (2012b), 18 months of non zero returns are required for the stock to be included in the portfolios.
Any Datastream padded price is removed by requesting X(P#S) $U which returns null values when Datastream does not have a record and any non equity item is removed by requiring the TYPE description in Datastream to be equal to EQ.

5. Data

Table 1: This table presents the descriptive statistics for the naïve infrastructure stock selection scheme, 2000-2014. Telecom, Transport and Utilities are portfolios of stocks that earn a minimum revenue level from activities related to SIC or GIC codes recognised as Telecommunications, Transport and Utilities industries, respectfully. The minimum revenue levels required are 50%, 75% and 90% , respectfully. Return is the average monthly return from January 2000 to December 2014. Risk is the monthly standard deviation of returns from January 2000 to December 2014. SR is the Sharpe Ratio calculated with the average yield of the U.S. one month Treasury bill as the risk free rate proxy. Worst Drawdown is the maximum drawdown ratio, measured as a percentage of maximum cumulative return i.e. from "peak equity.

Price returns

	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	MSCI World
Price return	−0.084	0.020	−0.005	0.012
Risk	0.179	0.154	0.152	0.158
SR	−0.496	0.094	−0.065	0.047
Worst Drawdown	0.830	0.620	0.570	0.550
	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	MSCI World
Price return	−0.092	0.068	0.003	0.012
Risk	0.185	0.198	0.133	0.158
SR	−0.522	0.318	−0.015	0.047
Worst Drawdown	0.830	0.690	0.500	0.550
	90% Rev Tel.	90% Rev Transp.	90% Rev Util.	MSCI World
Price return	−0.085	0.042	0.002	0.012
Risk	0.175	0.180	0.133	0.158
SR	−0.515	0.205	−0.025	0.047
Worst Drawdown	0.810	0.690	0.480	0.550

Total returns

	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	MSCI World
Tot. return	−0.052	0.048	0.028	0.036
Risk	0.180	0.152	0.153	0.159
SR	−0.315	0.282	0.148	0.197
Worst Drawdown	0.818	0.609	0.556	0.537
	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	MSCI World
Tot. return	−0.057	0.109	0.039	0.036
Risk	0.185	0.197	0.134	0.159
SR	−0.334	0.523	0.255	0.197
Worst Drawdown	0.826	0.667	0.473	0.537
	90% Rev Tel.	90% Rev Transp.	90% Rev Util.	MSCI World
Tot. return	−0.051	0.088	0.038	0.036
Risk	0.176	0.179	0.133	0.159
SR	−0.315	0.461	0.249	0.197
Worst Drawdown	0.799	0.662	0.454	0.537

5. Data

of each country covered. The index is updated quarterly with annual revisions to update the investable universe and the removal of stocks with low liquidity. Such market value-weighted indices, while they constitute a useful point of reference, have been shown to be highly inefficient in previous research (see Amenc et al., 2010).

Nevertheless, the listed infrastructure portfolios obtained above do not necessarily offer better risk-adjusted performance than this relatively unambitious baseline.

We observe that irrespective of the revenue cut-offs employed to form the infrastructure portfolios, the telecom sector continually produces poor returns. This sector does not seem to have recovered from the technology bubble of the yearly 2000s. This suggests that certain "infrastructure" sectors experience a high degree of cyclicality, as well as a complete absence of persistence. Transportation fares better with higher Sharpe ratios than the market index under both the price return and total return measures. However, drawdown risk is typically higher than the market's for price and total returns as shown in Table 1. During the sample period Utilities only outperform the broad market from a total return perspective.

Next, we describe our second test asset, a combination of rule-based and *ad hoc* stock selection schemes created by index providers.

5.2 Test assets - *Ad hoc* listed infrastructure indices

5.2.1 Asset selection

The basic requirements to be included in listed infrastructure indices created by index providers are not very different from the naïve selection scheme described above. They include:

1. being part of a broader index universe (usually that of the infrastructure universe of the index provider); and,
2. a minimum amount of revenue derived from infrastructure activities.

However, minimum revenue requirements and the definition of infrastructure activities are set differently by each index provider, adding what could amount to "active views", to a rule-based scheme.

We test two groups of listed infrastructure indices: a set of global indices and one designed to represent the U.S. market only. Global indices provide a direct comparison with the naïve approach described above, while a U.S.-only perspective allows more controls and granularity when designing a reference portfolio of asset classes or factors to test the mean-variance spanning of listed infrastructure indices.

Global Infrastructure Indices

We include seven global infrastructure indices and four U.S. infrastructure indices:[8]

- Dow Jones Brookfield Global Infrastructure Index;

8 - A brief summary of the indices is available upon request

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- FTSE Macquarie Global Infrastructure Index;
- FTSE Global Core Infrastructure;
- MSCI World Infrastructure Index;
- MSCI ACWI Infrastructure Capped;
- UBS Global Infrastructure and Utilities; and,
- UBS Global 50/50 Infrastructure and Utilities.

The universe thus recognised by index providers is not very large with only the MSCI World Infrastructure and MSCI ACWI Global Infrastructure representing more than 10% of the value of the MSCI World Index.

U.S. infrastructure indices

The U.S. infrastructure indices included in this study are:

- FTSE Macquarie USA Infrastructure Index;
- MSCI US Infrastructure Index;
- MSCI USA Infrastructure 20/35 Capped Index; and,
- Alerian MLP Infrastructure Index.

5.2.2 Descriptive statistics

Global Infrastructure Indices

Table 2 shows that most infrastructure indices have higher Sharpe ratios than the reference market index (MSCI World). The Dow Jones Brookfield Global Infrastructure index exhibits the highest average annualised returns and Sharpe ratio for the sample period. This performance is contrasted by the MSCI World Infrastructure index which exhibits negative performance on a price return basis. However Table 2 suggest that drawdown risk is very similar between infrastructure indices and the broad market, with the exception of the Brookfield and MSCI ACWI indices.

U.S. infrastructure indices

In the case of US-only indices, the MSCI and FTSE indices, reported in Table 3 do not seem to stand out from the broad market index (here the Russell 3000), but the Alerian MLP index, which captures a underlying business model focused on dividend distributions, exhibits very different characteristics. with much higher Sharpe ratios especially on a total return basis, but equally high maximum drawdown.

5.3 Test Assets - Listed baskets of contracted infrastructure projects

5.3.1 Asset selection

The PFI portfolio consists of

1. HSBC Infrastructure Company Ltd (HICL)
2. John Laing Infrastructure Fund Ltd (JLIF)
3. GCP Infrastructure Ltd (GCP)
4. International Partnerships Ltd (INPP)
5. Bilfinger Berger Global Infrastructure Ltd (BBGI)

As discussed, these firms are solely occupied with buying and holding the equity and quasi-equity of PFI (private finance initiative) project companies in existence in the U.K. and that of similar

5. Data

Table 2: This table presents the descriptive statistics for the Global Infrastructure Indices for the period, 2000-2014. BF is the Dow Jones Brookfield Global Infrastructure Index, SP is Standard & Poor's Global Infrastructure Index, FTSEM is the FTSE Macquarie Global Infrastructure Index, FTSEC is the FTSE Global Core Infrastructure Index, MSCI is the MSCI World Infrastructure Index, MSCIA is the MSCI ACWI Infrastructure Capped, UBS is the UBS Global Infrastructure and Utilities, UBS 50 is the UBS Global 50/50 Infrastructure and Utilities Index and MSCIW is the MSCI World Index. Return is the average monthly return from the index commencement date to December 2014. Risk is the monthly standard deviation of returns from the index commencement date to December 2014. SR is the Sharpe Ratio calculated with the average yield of the U.S. one month Treasury bill as the risk free rate proxy. Worst Drawdown is the maximum drawdown ratio, measured as a percentage of maximum cumulative return i.e. from "peak equity".

Price returns

	BF	SP	FTSEM	FTSEC	MSCI	MSCIA	UBS	UBS50	MSCIW
Return	0.112	0.072	0.043	0.063	−0.020	0.025	0.046	0.055	0.012
Risk	0.132	0.153	0.138	0.115	0.145	0.105	0.119	0.145	0.158
SR	0.807	0.436	0.273	0.507	−0.171	0.192	0.347	0.341	0.047
Worst Drawdown	0.476	0.551	0.456	0.374	0.660	0.424	0.447	0.505	0.554

Total returns

	BF	SP	FTSEM	FTSEC	MSCI	MSCIA	UBS	UBS50	MSCIW
Return	0.147	0.116	0.083	0.099	0.019	0.061	0.082	0.091	0.036
Risk	0.132	0.153	0.138	0.114	0.146	0.105	0.119	0.145	0.159
SR	1.070	0.725	0.561	0.820	0.092	0.532	0.644	0.588	0.197
Worst Drawdown	0.452	0.527	0.432	0.348	0.640	0.395	0.426	0.484	0.537

Table 3: This table presents the descriptive statistics for of annualised price and total returns of U.S. infrastructure stock indices, 2000-2014. AMLP is the Alerian MLP Infrastructure Index, FTSEM is the FTSE Macquarie USA Infrastructure Index, MSCI is the MSCI US Infrastructure Index, MSCISC is the MSCI USA Infrastructure 20/35 Capped Index and R3000 is the Russell 3000 index. Return is the average monthly return from January 2000 to December 2014. Risk is the monthly standard deviation of returns from January 2000 to December 2014. SR is the Sharpe Ratio calculated with the average yield of the U.S. one month Treasury bill as the risk free rate proxy. Worst Drawdown is the maximum drawdown ratio, measured as a percentage of maximum cumulative return i.e. from "peak equity".

Price returns

	AMLP	FTSEM	MSCI	MSCISC	R3000
Price return	0.130	0.063	−0.016	0.024	0.029
Risk	0.166	0.448	0.147	0.138	0.157
SR	0.748	0.130	−0.141	0.133	0.155
Worst Drawdown	0.492	0.956	0.633	0.448	0.527

Total returns

	AMLP	FTSEM	MSCI	MSCISC	R3000
ann. total return	0.213	0.067	0.021	0.055	0.048
ann. risk	0.170	0.448	0.148	0.138	0.157
ann. Sharpe ratio	1.219	0.137	0.106	0.361	0.274
Worst Drawdown	0.431	0.956	0.609	0.423	0.512

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firms mostly involved in delivering so-called availability-payment infrastructure projects, by which the public sector pays a pre-agreed income to the project firm on a regular basis in exchange for the construction/development, maintenance and operations of a given infrastructure project given a pre-agreed output specification and for several decades.

These PFI project companies in question do not enter into any other activities during their lifetime, and solely deliver the contracted infrastructure and associated services while repaying their creditors and investors. As such, they give access to a "pure" infrastructure project cash flow, representative of the underlying nature of the PFI business model.

The firms in the PFI portfolio can be considered useful proxies of a portfolio of PFI equity investments. While the project companies are typically highly leveraged, the firms in the PFI portfolio do not make a significant use of leverage. Hence, as a group, they can be considered to be representative a listed basket of PFI equity stakes.

All returns are annualised monthly price and total returns computed in local currency (GBP) and sourced from Datastream.

5.3.2 Descriptive Statistics

Table 4 suggest that the PFI portfolio possesses different characteristics than other listed infrastructure portfolios examined so far. Its Sharpe ratio is high but its maximum drawdown is much lower than the market reference (here the FTSE All Shares). Indeed, the maximum drawdown for the PFI portfolio is also much lower than the FTSE Macquarie Europe infrastructure index, another listed infrastructure index focused solely on European markets. The combination of high risk-adjusted performance with low drawdown risk is particularly striking in the total return case.

5.4 Reference Assets

As discussed above, we use two types of reference allocations to test the impact of adding listed infrastructure to an investor's universe, an asset class-based allocation and a factor-based allocation. All the summary statistics for the reference assets can be found in table 13 in the Appendix.

5.4.1 Global asset class-based reference portfolio

A "well diversified investor" in the traditional albeit imprecise meaning of the term can be expected to hold a number of different asset classes, including:

- Global Fixed Interest proxied by JP Morgan Global Aggregate Bond Index;
- Commodities proxied by The S&P Goldman Sachs Commodity Index;
- Real Estate proxied by MSCI World Real Estate Index;
- Hedge Funds proxied by Dow Jones Credit Suisse Hedge Fund Index; and,
- OECD and Emerging Market Equities proxied by MSCI World and MSCI Emerging Market Indices, respectively.

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Table 4: This table presents the descriptive statistics for of annualised price and total returns of the PFI portfolio, an infrastructure index and the market index, 2006-2014. The PFI Portfolio is the equal-weighted return of the PFI stocks identified listed on the London Stock Exchange. Return is the average monthly return from 2006 to December 2014. Risk is the monthly standard deviation of returns from 2006 to December 2014. SR is the Sharpe Ratio calculated with the average yield of the U.S. one month Treasury bill as the risk free rate proxy. Max. DD is the maximum drawdown ratio, measured as a percentage of maximum cumulative return i.e. from "peak equity". All returns are annualised monthly price and total returns computed in local currency (GBP) and sourced from Datastream.

Price returns

	PFI Portfolio	FTSE All Shares	Macquarie Infra Europe
Price return	0.048	0.027	−0.007
Risk	0.093	0.182	0.181
SR	0.460	0.121	−0.065
Max. DD	0.240	0.450	0.500

Total returns

	PFI Portfolio	FTSE All Shares	Macquarie Infra Europe
Tot. return	0.101	0.065	0.046
Risk	0.082	0.172	0.184
SR	1.171	0.345	0.224
Max. DD	0.150	0.410	0.370

One potential issue with employing indices as a reference asset is the possibility of double-counting infrastructure stocks in both the reference and test assets. This has the potential of biasing the mean-variance span tests against finding an improvement in the investment opportunity set. Whilst ideally removing any infrastructure like stocks from the reference assets would solve the problem of double counting, the circulation of index constituent lists is too limited to allow this.

However, the MSCI World Index, MSCI (2014) states that as at November 2014 the Utilities and Telecom industries comprise 3.32% and 3.46% whilst the Industrials sector comprises 10.89% and the share of "infrastructure" in industrials (e.g. railway) is small.

Whilst it would be preferable to exclude the infrastructure stocks from the MSCI World, we cannot know the constituents and so this cannot be done.

Nevertheless, given the low weighting its likely that any results will not be biased against the infrastructure stocks. We conclude that not isolating infrastructure stocks from our reference assets will not materially influence the conclusions of this study.

5.4.2 U.S. asset class reference portfolio

A typical U.S.-based reference portfolio built using traditional asset classes would include:

- Government Bonds proxied by the Barclays Govt Aggregate Index;
- Corporate Bonds represented by the Barclays U.S. Aggregate Index;
- High Yield Bonds with the Barclays U.S. Corporate High Yield;

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- Real Estate, as per the US-DataStream Real Estate Index;
- Hedge Funds represented by the Dow Jones Credit Suisse Hedge Fund Index;
- Commodities proxied by the S&P Goldman Sachs Commodity Index;
- U.S. Equities captured by the RUSSELL 3000[9]; and,
- World Equities represented by the MSCI World ex-US.

9 - The Russell 3000 index was selected for the U.S. equity market index for two reasons. Firstly, it represents the top 3,000 stocks by market capitalisation. This represents a significant proportion of the investable universe of U.S. stocks. Secondly, for consistency, in the factor exposure studies we employ the Russell indices to create the factor proxies.

5.4.3 U.K. asset class reference portfolio

To test the mean variance spanning properties of the PFI portfolio, we build a U.K. asset class reference portfolio consisting of:

- Fixed Interest, represented by the Bank of America/ML U.K. Gilts index;
- Real Estate, proxied by the DataStream U.K. Real estate Index;
- Hedge funds, represented by the U.K. DataStream hedge funds Index;
- Commodities, as proxied by the S&P Goldman Sachs Commodity Index;
- U.K. Equities represented by the FTSE100; and.
- World Equities proxied by the FTSE World ex-U.K.

5.4.4 Global factor-based reference portfolio

Consistent with prior research, the factors in this study are constructed from stock and bond market indices. We follow Bender et al. (2010), Ilmanen and Kizer (2012) and Bird et al. (2013) to build Market, Size, Value, Term and Default factors.

- The Market factor is the excess return of the MSCI U.S. and MSCI Europe indices.
- The Size factor (SMB) is calculated by taking the difference between the simple average of MSCI Small Value and Growth indices and the simple average of MSCI Large Value and Growth Indices.
- The Value factor (HML) is constructed by obtaining the difference between simple average of MSCI Small, Mid and Large Value indices and simple average of MSCI Small, Mid and Large Growth Indices.
- The Term factor is estimated by taking the difference between the returns of the U.S. Government 10 year index and S&P U.S. Treasury Bill 0-3 Index.
- Finally, the Default factor is estimated by the change in the Moody's Seasoned Baa Corporate Bond Yield Relative to the Yield on 10-Year Treasury Constant Maturity.

5.4.5 U.S. factor-based reference portfolio

U.S. factors are computed using the now canonical formulas reported in (Faff, 2001):

$$\text{Market} = \text{Russell 3000 Index} \\ - \text{US one month Treasury Bill return}$$

$$\text{SMB} = \frac{(Russell2000Value + Russell2000Growth)}{2} - \frac{(Russell1000Value + Russell1000Growth)}{2}$$

$$\text{HML} = \frac{(Russell1000Value + Russell2000Value)}{2} - \frac{(Russell1000Growth + Russell2000Growth)}{2}$$

$$\text{Term} = \text{Barclays US Treasury 10-20 years Index} \\ - \text{Barclays US Treasury Bills 1-3 months Index}$$

$$\text{Default} = \text{Barclays US Corporate: AAA Long Index} \\ - \text{Barclays US Treasury Long Index}$$

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In the next section, we present the results of the mean-variance spanning tests presented in section 4 using the multiple datasets described above.

6. Results

6. Results

We first present the results of the Mean-Variance Spanning tests conducted using the asset classes as the reference assets in section 6.1. Next, we use the factors defined above as the reference portfolio.

We report the Huberman and Kandel (1987) regression results for equation 4.1 and the corresponding Kan and Zhou (2012) two stage, step down tests.

6.1 Asset class mean-variance spanning test results

6.1.1 Listed infrastructure companies

The results of the mean-variance span test for the naïve infrastructure portfolios are reported in Table 5. For the price returns of the nine portfolios constructed, Table 5 shows that the reference investment opportunity set is improved by four of these portfolios. These are the 75% Revenue Cutoff Transport portfolio as well as the Telecommunication portfolios. However, when total returns are examined, only the 50% Telecoms and the 75% Transport infrastructure portfolio are found to reject the Huberman and Kandel (1987) null hypothesis of spanning at conventional significance levels. **Every other portfolio does not improve upon the mean-variance frontier created by the reference asset classes.**

Applying the Kan and Zhou (2012) methodology, the results in Table 5 **shows that none of the infrastructure portfolios improve the mean-variance frontier from that created by the reference investments.** Indeed, the listed infrastructure portfolios fail to improve either the tangent portfolio or produce a lower minimum variance portfolio. This finding is consistent when either price or total returns are used.

When the sub-periods are considered, both before and after the GFC, the conclusion that the naïve infrastructure approach fails to identify any diversification benefits is supported.

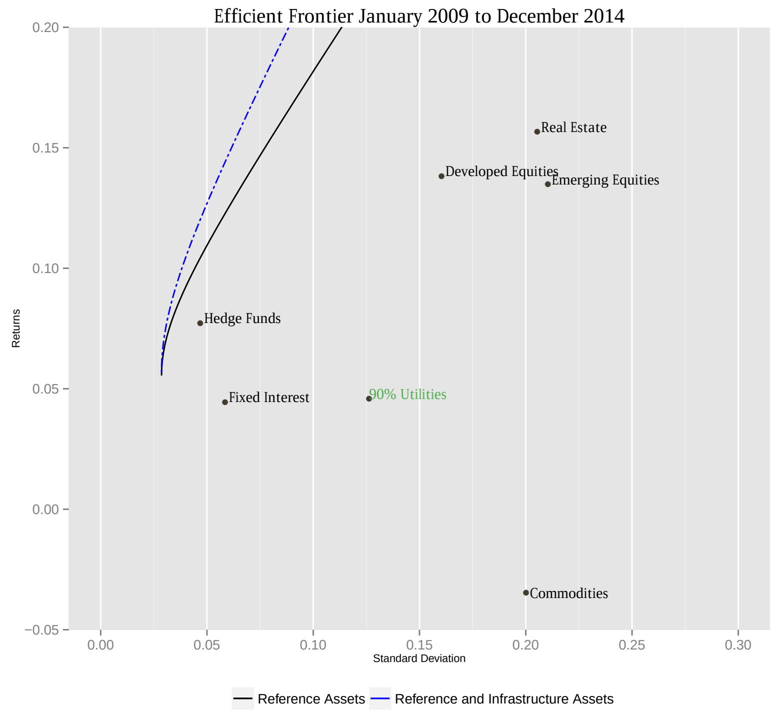
Panels B and D in Table 5 present the results for the Mean-Variance Spanning tests for the period January 2000 to December 2008. The Huberman and Kandel (1987) test's null hypothesis is rejected in two cases: the price and total returns of the 75% Transport portfolio. However, the Kan and Zhou (2012) test fails to reject the **null hypothesis that the reference portfolio *already spans* listed infrastructure**.

From January 2009 to December 2014 (Panel C and F in Table 5) only one portfolio is found to improve the efficient frontier, the price returns of the 50% Utilities portfolio. Here, the Huberman and Kandel (1987) portfolio's null hypothesis is rejected at the 5% significance level and both steps of the Kan and Zhou (2012) test reject the null hypothesis that the portfolio's risk and returns are already spanned by the reference assets.

This seldom provides systematic evidence of the existence of a listed infrastructure asset class.

6. Results

Figure 3: Mean-variance frontier of 90% revenue threshold utilities and asset class reference portfolio



An illustration of the findings in table 5 is shown in figure 3, which presents the mean-variance frontier with and without the addition of the naïve 90% Utilities portfolio for the period January 2009 to December 2014. The results in table 5 confirm that this portfolio does not improves the investment opportunity set despite shifting the efficient frontier to the left since the minimum variance point is not statistically different before and after adding "infrastructure" to the asset mix.

Next, we discuss our results using industry-provided infrastructure indices as proxies of the infrastructure asset class, testing whether there are diversification benefits with a global asset class-based reference portfolio.

Global infrastructure indices

Table 6 presents our results for the global infrastructure price and total return indices described in section 5. Here, using price returns for the full sample period (Panel A, Table 6), the Huberman and Kandel (1987) test finds an improvement in the efficient frontier in six of the eight infrastructure indices examined. However, the more restrictive Kan and Zhou (2012) test only finds two of the eight global infrastructure indices to improve the reference efficient frontier: the Dow Jones Brookfield Global Infrastructure index and the UBS Infrastructure and Utilities index.

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Other indices found to improve the efficient frontier by the Huberman and Kandel (1987) test are instead found to improve the tangency portfolio or the minimum variance portfolio but not both. As a result, it cannot be accepted that these indices improve the efficient frontier.

Using total returns (Panel D, table 6), again six of the eight global indices reject the null of the Huberman and Kandel (1987) test. Only the FTSE Core index fails to span when either the price or total returns are employed, while the MSCI World Infrastructure is not spanned by the reference asset classes using price returns but is when considering total returns. The reverse is true for the UBS 50-50.

Using the Kan and Zhou (2012) test, four of the eight global infrastructure indices are found to improve the efficient frontier. But table 6 shows that most indices found by the Huberman and Kandel (1987) test to improve the efficient frontier only improved the minimum variance portfolio, but not improve the tangency portfolio. As a result, it is not possible to conclude that these listed infrastructure indices are not spanned by existing asset classes.

Turning to sub-periods, for price returns pre-GFC (Panels B and C of table 6), the Huberman and Kandel (1987) test finds that four of the eight global listed infrastructure indices improve the efficient frontier. However, the Kan and Zhou (2012) test finds that these indices only improve the minimum variance portfolio, and not the tangency portfolio.

When total returns are considered for the same period, the Huberman and Kandel (1987) test finds all of the listed infrastructure indices improve the efficient frontier. The results of the Kan and Zhou (2012) test however, indicate that while during this period the global indices improved on the tangency portfolio, not all impacted the minimum variance portfolio. As a result, pre-GFC, only FTSE Core, MSCI World Infrastructure and the MSCI ACWI Capped infrastructure indices can be said to improve the efficient frontier, as they both improve the tangency portfolio and reduce the minimum variance portfolio for this period.

Post-GFC (panels E and F of table 6), pre-GFC results are invalidated. Using price returns, only one of the eight indices examined is found to improve the efficient frontier under both the Huberman and Kandel (1987) and Kan and Zhou (2012) tests: the Dow Jones Brookfield index. Using total returns again only one index is found to improve the efficient frontier under both the Huberman and Kandel (1987) and Kan and Zhou (2012) tests: the MSCI ACWI Capped index.

Hence, pre-GFC results are not persistent post-GFC. These results argue against the existence of a well-defined and persistent listed infrastructure "asset class".

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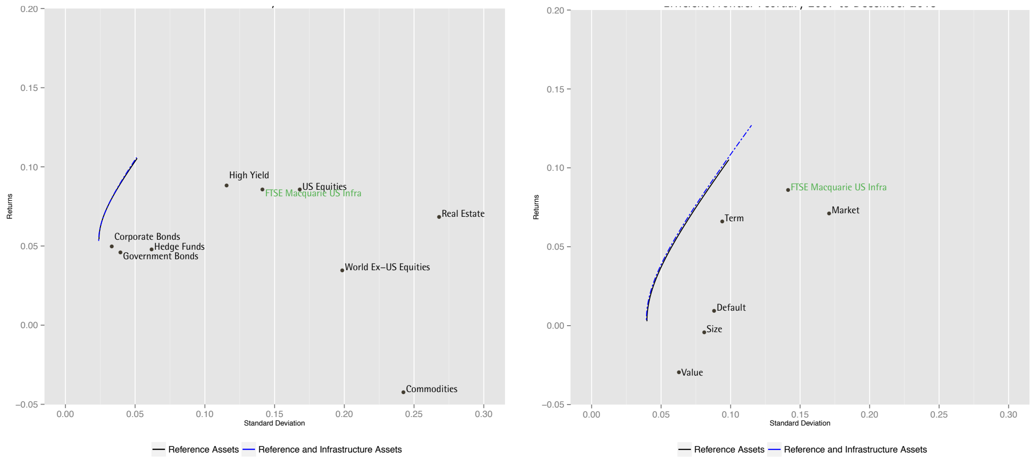
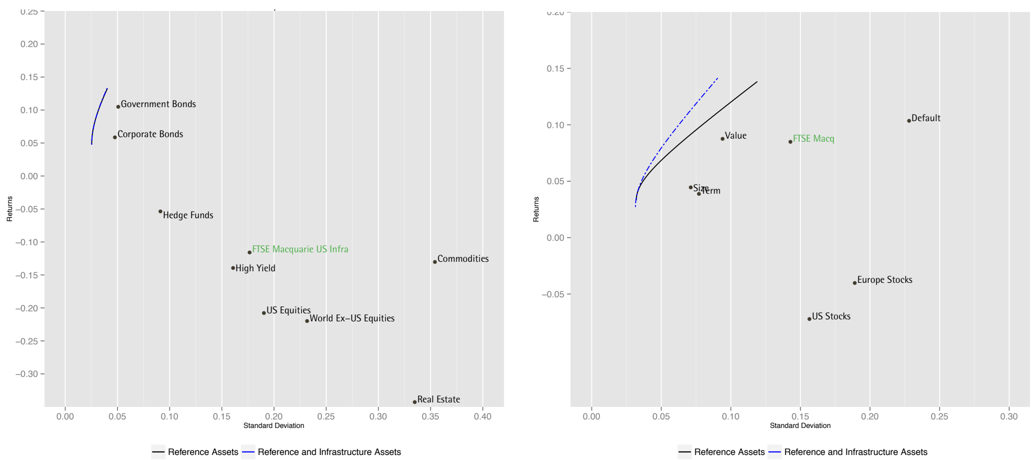
Figure 4: Illustration of the difference tests of mean-variance spanning of the FTSE Macquarie USA Infrastructure Index

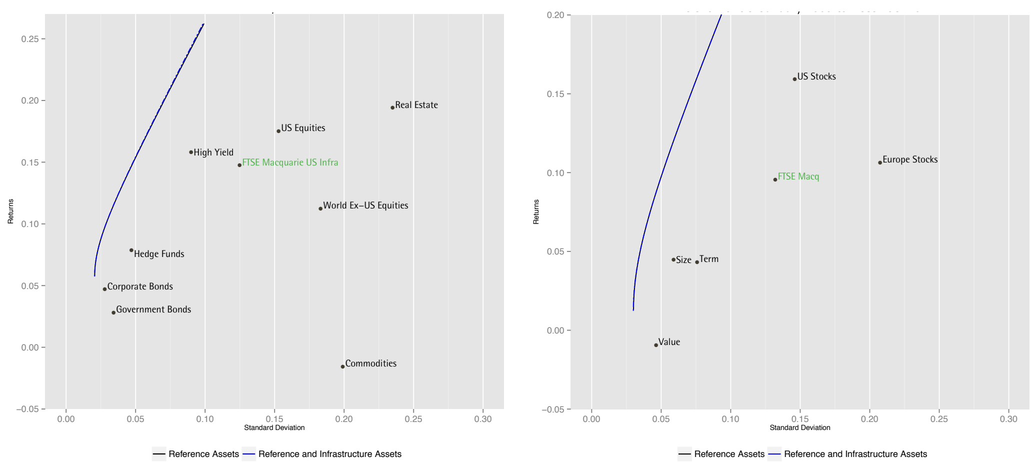
(a) 2000-2014, asset class and factor-based reference



(b) 2000-2008, asset class and factor-based reference



(c) 2009-2014, asset class and factor-based reference



6. Results

6.1.2 U.S. Infrastructure Indices

The results for U.S. listed infrastructure indices, are presented in table 7.

The Huberman and Kandel (1987) results in table 7 indicate that for the full period (Panel A and D) both the price returns and total returns of the Alerian Infrastructure MLP index improves on the efficient frontier. None of the other infrastructure indices reject the null hypothesis that the existing asset class investments span the risk and returns provided by the listed infrastructure indices. Figure 4 provides an illustration.

When the Kan and Zhou (2012) test is employed, the conclusion that the Alerian Infrastructure MLP index improves the investment opportunity set is reversed for both the price and total return indices. Whilst the Kan and Zhou (2012) finds that the tangency portfolio has improved, it does not reject the null hypothesis that the global minimum variance has improved. As a result, it is not possible to conclude that the inclusion of the Alerian Infrastructure MLP index improves the investment universe. As the other infrastructure indices do not reject the null hypothesis, the same conclusions apply.

When pre- and post-GFC sub-samples are considered (Panels B, C, E and F), the conclusion that listed infrastructure assets don't improve the investment universe, is still supported. For the first sub-period, only the total returns of the Alerian Infrastructure MLP index rejects the null hypothesis of the Huberman and Kandel (1987) test, as illustrated by figure 5.

When the Kan and Zhou (2012) test is employed, none of the indices can reject both steps of the test. It is not possible to conclude that the inclusion of infrastructure indices improves the mean-variance of traditional asset classes in that period.

Using the second sub-sample period, none of the indices, either using total or price returns, are found to reject the null hypothesis leading to the conclusion that none of the indices represent an improvement an investor's diversification opportunities.

6.1.3 PFI portfolio

Finally, we report the ability of our PFI portfolio to improve the mean-variance efficiency of a diversified investor in the United Kingdom in table 8. For the complete sample, the price return series does not provide diversification benefits. However, total return results are found to improve on the reference efficient frontier when investing over the entire period, as figure 6 illustrates. The total returns PFI portfolio passes both the Huberman and Kandel (1987) and the Kan and Zhou (2012) tests for the full sample period.

Looking at sub-periods in panels, diversification benefits appear only in the period following the GFC. Prior to the GFC, neither price nor total returns of the PFI portfolios improve the efficient frontier. Total returns for example produce diversification benefits

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Figure 5: Mean-Variance Frontier of Alerian MLP Index Asset Class Proxies

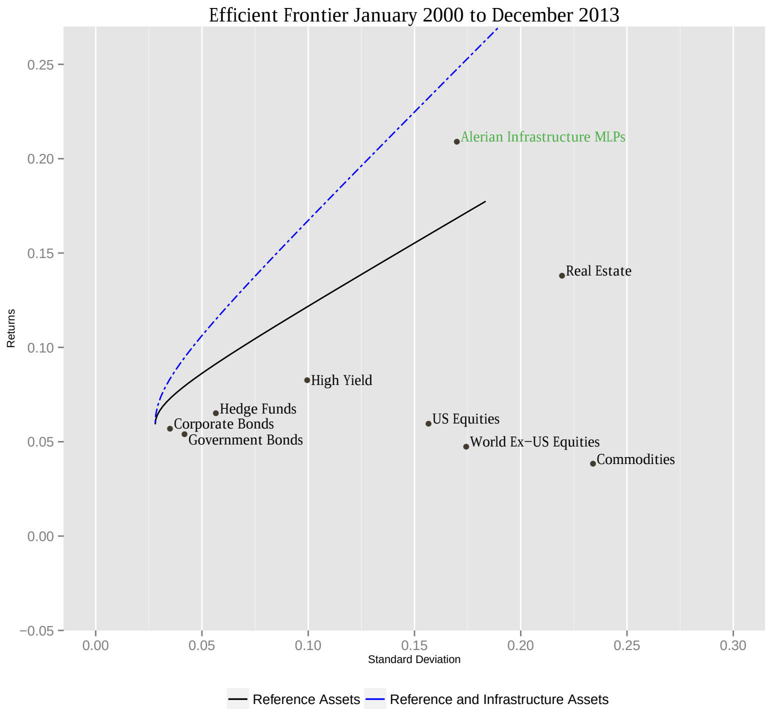
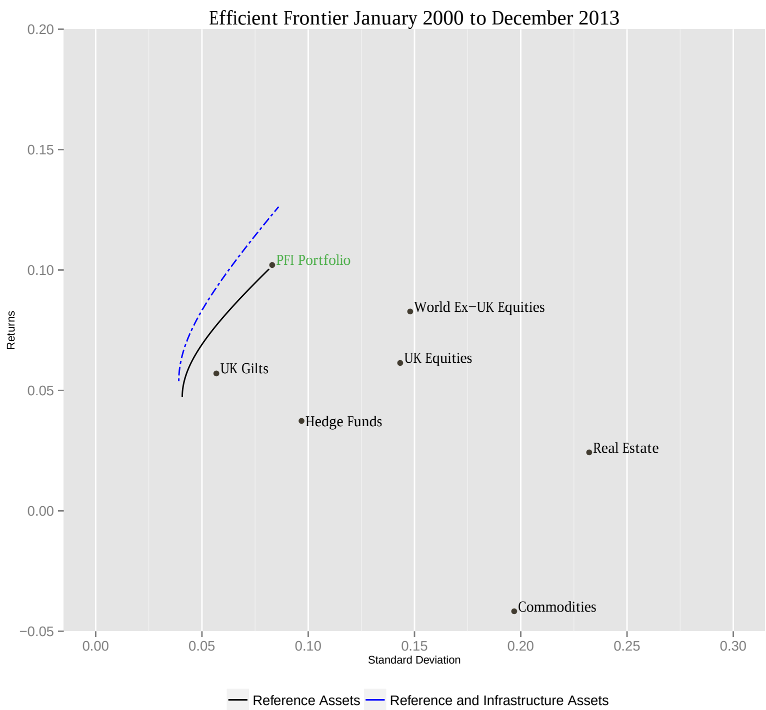


Figure 6: Mean-Variance Frontier of total returns PFI portfolio and reference portfolio, 2000-2014



6. Results

according to the Huberman and Kandel (1987) test, but the Kan and Zhou (2012) test finds that these benefits are only due to a change in the global minimum variance portfolio. Without a corresponding increase in the tangency portfolio, it is not possible to conclude that the efficient frontier has been improved. Still, these results may be considered inconclusive, as PFI portfolio returns begin in 2006.

After the GFC however, the price returns of the PFI portfolio, pass the Huberman and Kandel (1987) test, but the Kan and Zhou (2012) finds that this is only due to the improvement of the minimum variance portfolio but not the tangency portfolio. However, the total returns PFI portfolio is found to exhibit diversification benefits by both the Huberman and Kandel (1987) and Kan and Zhou (2012) tests.

Hence, the impact of the PFI portfolio appears to be one of the most persistent of the various "infrastructure" portfolios that were tested on a total returns basis. It improves diversification for the entire investment period and, crucially, **post-GFC, when all but one of the other infrastructure indices fails to pass the post-GFC test of persistence.**

6.2 Factor-based mean-variance spanning test results

Next, we examine how the different listed infrastructure definitions proposed above fare against a factor-based reference portfolio, i.e. whether investing in listed infrastructure creates an exposure to a combination of factors, which is not otherwise available to investors already allocating to the well-known factors described in section 5.4.

As above we first present our results for listed infrastructure companies (section 6.2.1), followed by global listed infrastructure (section 6.2.2) and US (section 6.2.3) infrastructure indices. Unfortunately, as this stage, we cannot build a reference factor portfolio for the UK for lack of sufficient data.

6.2.1 Listed infrastructure companies

Table 9 presents the our results for the infrastructure portfolios using the naïve infrastructure definition proposed in section 5. Using the full sample (panels A and D in table 9), the Huberman and Kandel (1987) rejects the null hypothesis that the efficient frontier is not improved in five of the nine price return indices and 6 of the nine total return indices. Applying the Kan and Zhou (2012) test however, there is no evidence that infrastructure, thus defined, provides diversification benefits. Indices that qualified under the Huberman and Kandel (1987) test all fail to reject the null hypothesis for both steps of the Kan and Zhou (2012) test. Consistent with the findings for the asset class reference portfolio, the addition of listed infrastructure companies to a factor-based allocation does not improve the mean-variance frontier.

6. Results

Pre- and post-GFC results are consistent with the full sample. In the period January 2000 to December 2008 (panels B and E in table 9), eight of the nine price return indices are found to improve the efficient frontier according to the Huberman and Kandel (1987) test. When the Kan and Zhou (2012) test is applied however, this positive result is overturned with none of the indices examined passing the two-stage test. When total returns are employed the results are the same.

For the period January 2009 to December 2014 (panels C and F in table 9), results mirror the pre-GFC sample. For the price return indices the Huberman and Kandel (1987) test finds that the mean variance frontier is improved in six of the naïve infrastructure portfolios. However, the Kan and Zhou (2012) test results do not support these findings and none of the portfolios qualify. The total returns for naïve infrastructure portfolios result in the same conclusions.

6.2.2 Global infrastructure indices

The results for the spanning tests for global listed infrastructure indices are presented in table 10. The results are now familiar.

Using price returns for the full sample (panels A in table 10), six of the eight indices examined reject the null of the Huberman and Kandel (1987) test at the 5% level, but the Kan and Zhou (2012) test indicates that only two of the eight indices improve both the tangency portfolio as well as the global minimum variance portfolio: only the Dow Jones Brookfield and FTSE Core Infrastructure index can be said to improve the reference efficient frontier.

For the period January 2000 to December 2008 (panels B in table 10), only four of the eight indices are found to reject the null of the Huberman and Kandel (1987) test at the 5% level, but none of these pass the Kan and Zhou (2012) test. Between January 2009 and December 2014 (panels C in table 10) only two of the eight portfolios are found to reject the null of the Huberman and Kandel (1987) test at the 5% level. Of these, only the Dow Jones Brookfield is found to improve the efficient frontier by the Kan and Zhou (2012) test.

Using total returns for the full sample period (panels D in table 10), all infrastructure indices examined reject the null of the Huberman and Kandel (1987) test at the 5% level; and four still pass the Kan and Zhou (2012) test: the S&P Global Infrastructure, FTSE Macquarie Index, MSCI ACWI Capped Index and the UBS 50-50 Index.

The same is true when the period January 2000 to December 2008 (panels E in table 10), is considered: all indices pass the Huberman and Kandel (1987) test and three (The FTSE Core, MSCI World Infrastructure and MSCI ACWI Infrastructure) are found by the Kan and Zhou (2012) test to improve the tangency portfolio and the global minimum variance portfolio, with The remainder are found to only improve the tangency portfolio.

6. Results

However, from January 2009 to December 2014, only three of the eight portfolios pass the Huberman and Kandel (1987) test and only one (the MSCI ACWI Capped Index) is found to improve the efficient frontier by the Kan and Zhou (2012) test on a total return basis.

6.2.3 U.S. infrastructure indices

Finally, Table 11 shows the same results using U.S. market indices and factors. For the full sample period and using price returns (Panel A in Table 11), the Alerian MLP Infrastructure index is, again, the only index found to improve the efficient frontier using the Huberman and Kandel (1987) test.

In the period from January 2000 to December 2008 (Panel B in Table 11), the Alerian MLP Infrastructure Index rejects the null hypothesis of the Huberman and Kandel (1987) test at the 5% level, but the Kan and Zhou (2012) test concludes that only the tangency portfolio has improved. In the post-GFC period (Panel C in Table 11), similar conclusions hold

Using total returns for the full sample period (Panel D in Table 11), only the Alerian MLP Infrastructure Index is again found to pass the Huberman and Kandel (1987) test, but the results of the Kan and Zhou (2012) test indicate that this is due to the Alerian MLP Infrastructure Index only improving the tangency portfolio.

From January 2000 to December 2008 (Panel E in Table 11), conclusions are the same. However, for the period from January 2009 to December 2014 (Panel F in Table 11), the Alerian MLP index passes both the Huberman and Kandel (1987) and Kan and Zhou (2012) tests, indicating that the efficient frontier has been improved.

Hence, the MLP index is found to have a somewhat similar spanning profile than the PFI portfolio in the sense that it manages to create diversification benefits both before after the GFC when considered from a total return perspective.

6. Results

Table 5: Mean-variance spanning results for Naïve infrastructure portfolios with asset class-built reference portfolio

Price returns									
Panel A	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	90% Rev Tel.	90% Rev Transp.	90% Rev Util.
H & K	5.9995	1.4399	1.4685	4.4346	9.4460	1.1629	4.7566	0.1140	0.9837
p-value	0.0030	0.2398	0.2331	0.0132	0.0001	0.3150	0.0098	0.8923	0.3760
Stepdown1	11.4124	0.6673	0.8408	8.1672	0.0605	0.3787	8.7251	0.1894	0.6453
p-value	0.0009	0.4151	0.3604	0.0048	0.8060	0.5391	0.0036	0.6639	0.4229
Stepdown2	0.5534	2.2168	2.0981	0.6742	18.9336	1.9541	0.7545	0.0388	1.3248
p-value	0.4579	0.1383	0.1493	0.4127	0.0000	0.1639	0.3862	0.8440	0.2513
Panel B	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	90% Rev Tel.	90% Rev Transp.	90% Rev Util.
H & K	2.7789	1.0327	0.3148	1.5847	5.1403	0.5791	1.3413	0.5641	0.2671
p-value	0.0669	0.3598	0.7307	0.2101	0.0075	0.5622	0.2662	0.5707	0.7661
Stepdown1	4.7052	0.5691	0.1516	2.6911	0.1091	0.3918	2.4454	0.0061	0.1606
p-value	0.0324	0.4524	0.6979	0.1041	0.7419	0.5328	0.1210	0.9379	0.6894
Stepdown2	0.8225	1.5027	0.4820	0.4704	10.2620	0.7712	0.2339	1.1333	0.3768
p-value	0.3666	0.2231	0.4891	0.4944	0.0018	0.3819	0.6297	0.2896	0.5407
Panel C	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	90% Rev Tel.	90% Rev Transp.	90% Rev Util.
H & K	1.9650	0.1961	9.4648	2.5562	1.5677	7.2259	2.4927	1.8230	5.5060
p-value	0.1484	0.8224	0.0002	0.0854	0.2163	0.0015	0.0906	0.1697	0.0062
Stepdown1	2.1676	0.3829	13.5665	2.7828	0.2542	11.5787	4.4232	0.0683	8.9767
p-value	0.1458	0.5382	0.0005	0.1001	0.6159	0.0011	0.0393	0.7946	0.0039
Stepdown2	1.7319	0.0094	4.5052	2.2683	2.9142	2.4763	0.5344	3.6290	1.8158
p-value	0.1927	0.9229	0.0375	0.1368	0.0925	0.1204	0.4673	0.0611	0.1824
Total returns									
Panel D	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	90% Rev Tel.	90% Rev Transp.	90% Rev Util.
H & K	4.1227	1.0944	0.7730	2.8372	9.9398	0.7009	2.8997	0.8547	0.3654
p-value	0.0178	0.3371	0.4632	0.0613	0.0001	0.4975	0.0577	0.4272	0.6945
Stepdown1	7.8185	0.0279	0.0069	5.0241	0.3657	0.1568	4.8271	1.6359	0.0590
p-value	0.0058	0.8677	0.9340	0.0263	0.5462	0.6926	0.0293	0.2026	0.8083
Stepdown2	0.4109	2.1730	1.5479	0.6356	19.5852	1.2512	0.9514	0.0732	0.6754
p-value	0.5223	0.1423	0.2151	0.4264	0.0000	0.2649	0.3307	0.7870	0.4123
Panel E	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	90% Rev Tel.	90% Rev Transp.	90% Rev Util.
H & K	2.3508	0.6169	0.6647	1.2237	4.7298	1.1515	0.8439	1.1320	0.7195
p-value	0.1005	0.5416	0.5167	0.2985	0.0109	0.3203	0.4330	0.3265	0.4895
Stepdown1	3.7987	0.2847	0.8781	1.9978	0.0220	1.6295	1.6151	0.2724	1.1584
p-value	0.0541	0.5948	0.3510	0.1606	0.8824	0.2047	0.2067	0.6029	0.2844
Stepdown2	0.8786	0.9560	0.4519	0.4452	9.5298	0.6693	0.0724	2.0062	0.2803
p-value	0.3508	0.3305	0.5030	0.5061	0.0026	0.4152	0.7884	0.1597	0.5977
Panel F	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	90% Rev Tel.	90% Rev Transp.	90% Rev Util.
H & K	0.4033	0.0241	4.7507	0.5286	3.0172	3.9925	0.2831	3.1475	2.9174
p-value	0.6698	0.9762	0.0119	0.5919	0.0558	0.0232	0.7544	0.0496	0.0612
Stepdown1	0.0182	0.0000	6.7268	0.0004	1.7058	6.8025	0.3114	0.4509	5.1591
p-value	0.8932	0.9982	0.0117	0.9842	0.1961	0.0113	0.5787	0.5043	0.0264
Stepdown2	0.8004	0.0490	2.5531	1.0731	4.2828	1.0868	0.2574	5.8931	0.6357
p-value	0.3742	0.8255	0.1149	0.3040	0.0424	0.3010	0.6136	0.0179	0.4281

6. Results

Table 6: Mean-variance spanning test results for global listed infrastructure indices with asset class-built reference portfolio

Price returns

Panel A	Dow Jones Brookfield	S&P Global Infra	FTSE Macquarie	FTSE Core	MSCI World Infra	MSCI ACWI Capped	UBS	UBS 50-50
H & K	6.2379	10.4252	3.1041	1.1562	3.1364	16.4068	7.8483	3.0324
p-value	0.0026	0.0001	0.0475	0.3188	0.0459	0.0000	0.0005	0.0508
Stepdown1	4.2128	0.0823	0.0125	1.2090	3.9114	2.6229	4.0417	1.5627
p-value	0.0420	0.7746	0.9110	0.2742	0.0495	0.1072	0.0459	0.2130
Stepdown2	8.0749	20.8950	6.2323	1.1011	2.3224	29.9118	11.4546	4.4876
p-value	0.0052	0.0000	0.0135	0.2965	0.1293	0.0000	0.0009	0.0356

Panel B	Dow Jones Brookfield	S&P Global Infra	FTSE Macquarie	FTSE Core	MSCI World Infra	MSCI ACWI Capped	UBS	UBS 50-50
H & K	3.0164	8.6243	4.4154	2.2605	2.9377	10.5604	5.5502	2.5240
p-value	0.0560	0.0004	0.0147	0.1230	0.0576	0.0001	0.0052	0.0852
Stepdown1	1.8074	0.9489	1.0874	2.4140	0.7302	2.0287	3.2296	3.0950
p-value	0.1836	0.3331	0.2997	0.1315	0.3948	0.1575	0.0753	0.0816
Stepdown2	4.1735	16.3104	7.7363	2.0090	5.1589	18.8996	7.7009	1.9133
p-value	0.0451	0.0001	0.0065	0.1670	0.0252	0.0000	0.0066	0.1696

Panel C	Dow Jones Brookfield	S&P Global Infra	FTSE Macquarie	FTSE Core	MSCI World Infra	MSCI ACWI Capped	UBS	UBS 50-50
H & K	3.7596	1.1947	1.2867	0.2095	0.8007	3.0735	2.1329	1.3365
p-value	0.0285	0.3093	0.2831	0.8115	0.4534	0.0530	0.1267	0.2699
Stepdown1	3.7266	0.8322	2.5164	0.4114	1.5921	0.4940	0.2978	0.5041
p-value	0.0579	0.3650	0.1175	0.5235	0.2115	0.4847	0.5872	0.4802
Stepdown2	3.6421	1.5613	0.0557	0.0078	0.0092	5.6966	4.0106	2.1854
p-value	0.0607	0.2159	0.8141	0.9300	0.9240	0.0199	0.0493	0.1441

Total returns

Panel D	Dow Jones Brookfield	S&P Global Infra	FTSE Macquarie	FTSE Core	MSCI World Infra	MSCI ACWI Capped	UBS	UBS 50-50
H & K	8.7138	13.8824	4.5856	2.8989	2.0253	17.6365	8.9542	4.8912
p-value	0.0003	0.0000	0.0115	0.0597	0.1351	0.0000	0.0002	0.0086
Stepdown1	7.9255	2.9554	0.8898	3.9974	0.8027	8.3858	7.9378	4.3504
p-value	0.0056	0.0877	0.3469	0.0483	0.3715	0.0043	0.0054	0.0385
Stepdown2	9.0480	24.4921	8.2868	1.7490	3.2516	25.7925	9.5882	5.3294
p-value	0.0031	0.0000	0.0045	0.1890	0.0731	0.0000	0.0023	0.0221

Panel E	Dow Jones Brookfield	S&P Global Infra	FTSE Macquarie	FTSE Core	MSCI World Infra	MSCI ACWI Capped	UBS	UBS 50-50
H & K	4.1011	11.4168	6.0174	2.9031	2.9696	11.4718	6.2768	3.8680
p-value	0.0211	0.0000	0.0035	0.0715	0.0559	0.0000	0.0027	0.0241
Stepdown1	3.1992	4.0673	2.9175	3.3744	0.0282	4.7157	5.6679	5.4413
p-value	0.0784	0.0472	0.0909	0.0769	0.8669	0.0323	0.0192	0.0217
Stepdown2	4.8393	18.0563	8.9370	2.2478	5.9684	17.5811	6.5815	2.1979
p-value	0.0314	0.0001	0.0036	0.1446	0.0163	0.0001	0.0118	0.1413

Panel F	Dow Jones Brookfield	S&P Global Infra	FTSE Macquarie	FTSE Core	MSCI World Infra	MSCI ACWI Capped	UBS	UBS 50-50
H & K	5.9270	1.3337	0.2773	1.1776	0.1752	3.7857	2.5662	1.2466
p-value	0.0043	0.2706	0.7587	0.3145	0.8397	0.0278	0.0846	0.2943
Stepdown1	7.1569	0.0031	0.5185	2.1403	0.0143	3.5961	0.9395	0.0490
p-value	0.0094	0.9556	0.4741	0.1483	0.9051	0.0624	0.3360	0.8255
Stepdown2	4.2964	2.7051	0.0364	0.2113	0.3411	3.8247	4.1967	2.4799
p-value	0.0421	0.1048	0.8493	0.6473	0.5612	0.0547	0.0445	0.1201

6. Results

Table 7: Mean Variance Span test results for the U.S. listed infrastructure indices with asset class-built reference portfolio

Price returns

Panel A	Alerian MLP	FTSE Macquarie USA	MSCI USA Infrastructure	MSCI USA Infra. Capped
H & K	3.5537	0.9730	0.4046	1.7772
p-value	0.0308	0.3821	0.6679	0.1722
Stepdown1	6.8957	0.0604	0.0512	0.3592
p-value	0.0094	0.8064	0.8212	0.5498
Stepdown2	0.2048	1.9064	0.7622	3.2072
p-value	0.6515	0.1709	0.3839	0.0751
Panel B	**Alerian MLP**	**FTSE Macquarie USA**	**MSCI USA Infrastructure**	**MSCI USA Infra. Capped**
H & K	1.9041	0.3161	0.4258	2.2540
p-value	0.1544	0.7349	0.6545	0.1104
Stepdown1	3.7423	0.5859	0.0962	0.1576
p-value	0.0559	0.4588	0.7570	0.6922
Stepdown2	0.0640	0.0477	0.7623	4.3878
p-value	0.8008	0.8305	0.3847	0.0388
Panel C	**Alerian MLP**	**FTSE Macquarie USA**	**MSCI USA Infrastructure**	**MSCI USA Infra. Capped**
H & K	0.8072	0.1190	0.0891	0.0867
p-value	0.4507	0.8880	0.9148	0.9171
Stepdown1	1.6137	0.0577	0.1382	0.0350
p-value	0.2086	0.8109	0.7114	0.8523
Stepdown2	0.0007	0.1830	0.0407	0.1405
p-value	0.9797	0.6702	0.8408	0.7090

Total returns

Panel D	Alerian MLP	FTSE Macquarie USA	MSCI USA Infrastructure	MSCI USA Infra. Capped
H & K	6.0024	1.1463	0.6895	1.9286
p-value	0.0030	0.3227	0.5032	0.1485
Stepdown1	11.6155	0.0121	0.0246	0.9511
p-value	0.0008	0.9128	0.8756	0.3308
Stepdown2	0.3666	2.3070	1.3622	2.9069
p-value	0.5456	0.1325	0.2448	0.0900
Panel E	**Alerian MLP**	**FTSE Macquarie USA**	**MSCI USA Infrastructure**	**MSCI USA Infra. Capped**
H & K	3.8572	0.2963	0.5864	2.3219
p-value	0.0244	0.7488	0.5583	0.1035
Stepdown1	7.4502	0.4998	0.0063	0.2440
p-value	0.0075	0.4931	0.9368	0.6225
Stepdown2	0.2480	0.0966	1.1783	4.4336
p-value	0.6196	0.7609	0.2803	0.0378
Panel F	**Alerian MLP**	**FTSE Macquarie USA**	**MSCI USA Infrastructure**	**MSCI USA Infra. Capped**
H & K	0.7444	0.1307	0.4085	0.3702
p-value	0.4791	0.8777	0.6664	0.6921
Stepdown1	1.3711	0.0963	0.7868	0.3305
p-value	0.2460	0.7574	0.3784	0.5674
Stepdown2	0.1171	0.1674	0.0304	0.4143
p-value	0.7333	0.6838	0.8622	0.5221

Table 8: Mean-variance spanning test results for the PFI stocks with asset class-built reference portfolio

Price returns

	Full Sample
H & K	0.4211
p-value	0.6575
Stepdown1	0.0000
p-value	0.9997
Stepdown2	0.8508
p-value	0.3586
	Pre-GFC
H & K	0.4173
p-value	0.6630
Stepdown1	0.6413
p-value	0.4302
Stepdown2	0.1959
p-value	0.6615
	Post-GFC
H & K	7.9863
p-value	0.0008
Stepdown1	1.1721
p-value	0.2830
Stepdown2	14.7621
p-value	0.0003

Total returns

	Full Sample
H & K	5.7016
p-value	0.0045
Stepdown1	5.4260
p-value	0.0219
Stepdown2	5.7239
p-value	0.0186
	Pre-GFC
H & K	1.3958
p-value	0.2649
Stepdown1	1.4184
p-value	0.2440
Stepdown2	1.3529
p-value	0.2546
	Post-GFC
H & K	7.6910
p-value	0.0010
Stepdown1	9.1745
p-value	0.0035
Stepdown2	5.5234
p-value	0.0218

6. Results

Table 9: Mean Variance Span test results for the factor asset class and the Naïve infrastructure portfolios with factor-based reference portfolios

Price returns

Full Sample	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	90% Rev Tel.	90% Rev Transp.	90% Rev Util.
H & K	47.8309	2.6335	1.8876	41.8602	3.4973	1.3880	37.0500	3.3250	0.9726
p-value	0.0000	0.0747	0.1545	0.0000	0.0324	0.2523	0.0000	0.0383	0.3801
Stepdown1	0.0268	1.0904	0.0796	0.0072	6.0392	0.1121	0.0293	1.8583	0.0551
p-value	0.8702	0.2978	0.7781	0.9323	0.0150	0.7382	0.8644	0.1746	0.8147
Stepdown2	96.1669	4.1744	3.7149	84.1880	0.9289	2.6775	74.4815	4.7685	1.9003
p-value	0.0000	0.0425	0.0555	0.0000	0.3365	0.1036	0.0000	0.0303	0.1698
Pre-GFC	**50% Rev Tel.**	**50% Rev Transp.**	**50% Rev Util.**	**75% Rev Tel.**	**75% Rev Transp.**	**75% Rev Util.**	**90% Rev Tel.**	**90% Rev Transp.**	**90% Rev Util.**
H & K	19.1594	3.4947	4.5904	19.7341	1.5564	3.1284	14.6323	6.6493	2.6374
p-value	0.0000	0.0340	0.0123	0.0000	0.2159	0.0480	0.0000	0.0019	0.0764
Stepdown1	1.3241	0.1873	1.8145	1.1258	1.5529	1.4435	0.9763	0.3731	0.9605
p-value	0.2526	0.6661	0.1809	0.2912	0.2156	0.2324	0.3254	0.5427	0.3294
Stepdown2	36.8786	6.8562	7.3084	38.2956	1.5515	4.7927	28.2949	13.0045	4.3160
p-value	0.0000	0.0102	0.0080	0.0000	0.2157	0.0308	0.0000	0.0005	0.0402
Post-GFC	**50% Rev Tel.**	**50% Rev Transp.**	**50% Rev Util.**	**75% Rev Tel.**	**75% Rev Transp.**	**75% Rev Util.**	**90% Rev Tel.**	**90% Rev Transp.**	**90% Rev Util.**
H & K	8.5824	2.0454	4.8455	5.5339	3.2293	0.8911	6.7757	3.7488	0.7437
p-value	0.0005	0.1373	0.0108	0.0060	0.0458	0.4150	0.0021	0.0286	0.4792
Stepdown1	0.0032	0.2274	5.7212	0.3092	3.3858	1.7022	0.0340	1.2738	1.1817
p-value	0.9548	0.6350	0.0196	0.5800	0.0702	0.1965	0.8542	0.2631	0.2809
Stepdown2	17.4170	3.9078	3.7121	10.8691	2.9687	0.0791	13.7121	6.1988	0.3049
p-value	0.0001	0.0521	0.0582	0.0016	0.0894	0.7794	0.0004	0.0152	0.5826

Total returns

Full Sample	50% Rev Tel.	50% Rev Transp.	50% Rev Util.	75% Rev Tel.	75% Rev Transp.	75% Rev Util.	90% Rev Tel.	90% Rev Transp.	90% Rev Util.
H & K	49.0714	4.1465	2.4766	44.8485	5.3390	2.0835	38.3526	4.7065	1.6385
p-value	0.0000	0.0174	0.0870	0.0000	0.0056	0.1276	0.0000	0.0102	0.1972
Stepdown1	0.6454	1.4520	0.3163	0.6925	9.5743	0.8237	0.5196	4.0237	0.6781
p-value	0.4228	0.2298	0.5745	0.4064	0.0023	0.3654	0.4720	0.0464	0.4114
Stepdown2	97.6941	6.8235	4.6550	89.1603	1.0524	3.3467	76.3942	5.2982	2.6038
p-value	0.0000	0.0098	0.0323	0.0000	0.3064	0.0690	0.0000	0.0225	0.1084
Pre-GFC	**50% Rev Tel.**	**50% Rev Transp.**	**50% Rev Util.**	**75% Rev Tel.**	**75% Rev Transp.**	**75% Rev Util.**	**90% Rev Tel.**	**90% Rev Transp.**	**90% Rev Util.**
H & K	23.2175	4.4858	5.2056	23.3121	2.0385	3.7743	18.4482	6.8887	3.3058
p-value	0.0000	0.0136	0.0070	0.0000	0.1355	0.0262	0.0000	0.0016	0.0406
Stepdown1	2.8219	0.1478	2.0863	2.2061	2.5522	2.3533	2.1082	0.9129	1.7675
p-value	0.0960	0.7014	0.1517	0.1405	0.1132	0.1281	0.1496	0.3416	0.1867
Stepdown2	42.8549	8.8974	8.2379	43.9038	1.5023	5.1278	34.4179	12.8754	4.8083
p-value	0.0000	0.0036	0.0050	0.0000	0.2231	0.0256	0.0000	0.0005	0.0306
Post-GFC	**50% Rev Tel.**	**50% Rev Transp.**	**50% Rev Util.**	**75% Rev Tel.**	**75% Rev Transp.**	**75% Rev Util.**	**90% Rev Tel.**	**90% Rev Transp.**	**90% Rev Util.**
H & K	5.2249	1.6536	3.3435	3.8623	4.5354	0.4192	3.7247	5.2298	0.3791
p-value	0.0078	0.1991	0.0413	0.0259	0.0142	0.6593	0.0293	0.0078	0.6859
Stepdown1	0.6878	0.9210	3.2420	0.4323	5.7151	0.7647	0.3616	3.4145	0.4485
p-value	0.4099	0.3407	0.0763	0.5131	0.0196	0.3850	0.5496	0.0690	0.5053
Stepdown2	9.8071	2.3890	3.3352	7.3537	3.1381	0.0739	7.1550	6.8036	0.3123
p-value	0.0026	0.1268	0.0722	0.0085	0.0810	0.7866	0.0094	0.0112	0.5781

6. Results

Table 10: Mean Variance Span test results for the Global listed infrastructure indices with factor-based reference portfolios

Price returns

Full Sample	Dow Jones Brookfield	S&P Global Infra	FTSE Macquarie	FTSE Core	MSCI World Infra	MSCI ACWI Capped	UBS	UBS 50-50
H & K	6.2379	10.4252	3.1041	1.1562	3.1364	16.4068	7.8483	3.0324
p-value	0.0026	0.0001	0.0475	0.3188	0.0459	0.0000	0.0005	0.0508
Stepdown1	4.2128	0.0823	0.0125	1.2090	3.9114	2.6229	4.0417	1.5627
p-value	0.0420	0.7746	0.9110	0.2742	0.0495	0.1072	0.0459	0.2130
Stepdown2	8.0749	20.8950	6.2323	1.1011	2.3224	29.9118	11.4546	4.4876
p-value	0.0052	0.0000	0.0135	0.2965	0.1293	0.0000	0.0009	0.0356
Pre-GFC	**Dow Jones Brookfield**	**S&P Global Infra**	**FTSE Macquarie**	**FTSE Core**	**MSCI World Infra**	**MSCI ACWI Capped**	**UBS**	**UBS 50-50**
H & K	3.0164	8.6243	4.4154	2.2605	2.9377	10.5604	5.5502	2.5240
p-value	0.0560	0.0004	0.0147	0.1230	0.0576	0.0001	0.0052	0.0852
Stepdown1	1.8074	0.9489	1.0874	2.4140	0.7302	2.0287	3.2296	3.0950
p-value	0.1836	0.3331	0.2997	0.1315	0.3948	0.1575	0.0753	0.0816
Stepdown2	4.1735	16.3104	7.7363	2.0090	5.1589	18.8996	7.7009	1.9133
p-value	0.0451	0.0001	0.0065	0.1670	0.0252	0.0000	0.0066	0.1696
Post-GFC A	**Dow Jones Brookfield**	**S&P Global Infra**	**FTSE Macquarie**	**FTSE Core**	**MSCI World Infra**	**MSCI ACWI Capped**	**UBS**	**UBS 50-50**
H & K	6.5136	0.6060	0.0344	1.8708	2.8372	4.4366	2.1674	1.7735
p-value	0.0026	0.5485	0.9662	0.1620	0.0657	0.0155	0.1224	0.1776
Stepdown1	8.3745	0.9974	0.0595	2.3981	0.5068	2.1816	4.3189	3.4760
p-value	0.0051	0.3215	0.8081	0.1262	0.4790	0.1444	0.0415	0.0666
Stepdown2	4.1975	0.2146	0.0096	1.3164	5.2053	6.5773	0.0151	0.0684
p-value	0.0443	0.6447	0.9224	0.2553	0.0257	0.0125	0.9025	0.7944

Total returns

Full Sample	Dow Jones Brookfield	S&P Global Infra	FTSE Macquarie	FTSE Core	MSCI World Infra	MSCI ACWI Capped	UBS	UBS 50-50
H & K	9.3519	12.1028	5.7400	5.1611	12.4659	9.6688	3.9037	10.4645
p-value	0.0002	0.0000	0.0039	0.0073	0.0000	0.0001	0.0220	0.0001
Stepdown1	18.0756	15.6201	6.1167	7.4542	1.8860	9.5355	7.7860	10.9591
p-value	0.0000	0.0001	0.0144	0.0075	0.1714	0.0023	0.0059	0.0011
Stepdown2	0.5590	7.8277	5.2047	2.6972	22.9290	9.3438	0.0207	9.4302
p-value	0.4559	0.0058	0.0238	0.1036	0.0000	0.0026	0.8857	0.0025
Pre-GFC	**Dow Jones Brookfield**	**S&P Global Infra**	**FTSE Macquarie**	**FTSE Core**	**MSCI World Infra**	**MSCI ACWI Capped**	**UBS**	**UBS 50-50**
H & K	7.0486	8.3514	4.5794	9.2948	21.4088	7.4560	4.0881	8.3279
p-value	0.0017	0.0005	0.0126	0.0007	0.0000	0.0010	0.0196	0.0004
Stepdown1	13.2588	16.6604	8.7027	9.1231	4.4843	9.8566	8.0081	14.1227
p-value	0.0005	0.0001	0.0040	0.0051	0.0366	0.0022	0.0056	0.0003
Stepdown2	0.7087	0.0354	0.4225	7.5010	37.0790	4.6552	0.1573	2.2468
p-value	0.4029	0.8512	0.5172	0.0101	0.0000	0.0333	0.6925	0.1370
Post-GFC	**Dow Jones Brookfield**	**S&P Global Infra**	**FTSE Macquarie**	**FTSE Core**	**MSCI World Infra**	**MSCI ACWI Capped**	**UBS**	**UBS 50-50**
H & K	7.3691	1.2262	0.3480	2.6625	3.0381	5.9643	3.5165	2.3387
p-value	0.0013	0.2999	0.7074	0.0771	0.0546	0.0041	0.0353	0.1043
Stepdown1	11.0624	2.0731	0.6576	4.2455	2.3362	6.9264	6.9994	4.3885
p-value	0.0014	0.1546	0.4203	0.0432	0.1311	0.0105	0.0102	0.0400
Stepdown2	3.2020	0.3734	0.0386	1.0304	3.6679	4.6012	0.0309	0.2753
p-value	0.0780	0.5432	0.8448	0.3137	0.0597	0.0355	0.8610	0.6015

6. Results

Table 11: Mean Variance Span test results for the factor asset classes and U.S. listed infrastructure indices with factor-based reference portfolios

Price returns

Full Sample	Alerian MLP	FTSE Macquarie USA	MSCI USA Infrastructure	MSCI USA Infra. Capped
H & K	8.0362	1.0298	1.0553	0.1836
p-value	0.0005	0.3613	0.3503	0.8324
Stepdown1	8.7670	0.0449	0.5795	0.2557
p-value	0.0035	0.8326	0.4475	0.6137
Stepdown2	6.9949	2.0365	1.5348	0.1120
p-value	0.0089	0.1571	0.2170	0.7383
Pre-GFC	**Alerian MLP**	**FTSE Macquarie USA**	**MSCI USA Infrastructure**	**MSCI USA Infra. Capped**
H & K	3.2144	1.3422	0.0637	0.6650
p-value	0.0443	0.2909	0.9383	0.5165
Stepdown1	6.4173	0.0560	0.1059	0.6719
p-value	0.0128	0.8161	0.7455	0.4143
Stepdown2	0.0109	2.7932	0.0216	0.6601
p-value	0.9171	0.1141	0.8833	0.4184
Post-GFC	**Alerian MLP**	**FTSE Macquarie USA**	**MSCI USA Infrastructure**	**MSCI USA Infra. Capped**
H & K	0.8072	0.1190	0.0891	0.0867
p-value	0.4507	0.8880	0.9148	0.9171
Stepdown1	1.6137	0.0577	0.1382	0.0350
p-value	0.2086	0.8109	0.7114	0.8523
Stepdown2	0.0007	0.1830	0.0407	0.1405
p-value	0.9797	0.6702	0.8408	0.7090

Total returns

Full Sample	Alerian MLP	FTSE Macquarie USA	MSCI USA Infrastructure	MSCI USA Infra. Capped
H & K	12.4051	0.9491	1.3303	0.1821
p-value	0.0000	0.3910	0.2671	0.8337
Stepdown1	21.9107	0.1018	0.3802	0.3176
p-value	0.0000	0.7505	0.5383	0.5738
Stepdown2	2.5900	1.8147	2.2886	0.0468
p-value	0.1093	0.1814	0.1321	0.8289
Pre-GFC	**Alerian MLP**	**FTSE Macquarie USA**	**MSCI USA Infrastructure**	**MSCI USA Infra. Capped**
H & K	5.4190	0.9820	0.0060	0.5267
p-value	0.0058	0.3974	0.9940	0.5921
Stepdown1	9.8783	0.0571	0.0001	0.0966
p-value	0.0022	0.8144	0.9938	0.7565
Stepdown2	0.8830	2.0263	0.0121	0.9654
p-value	0.3496	0.1738	0.9127	0.3282
Post-GFC	**Alerian MLP**	**FTSE Macquarie USA**	**MSCI USA Infrastructure**	**MSCI USA Infra. Capped**
H & K	16.3809	0.8787	1.0270	1.6919
p-value	0.0000	0.4201	0.3637	0.1921
Stepdown1	8.4217	1.2882	0.8764	0.9380
p-value	0.0050	0.2605	0.3526	0.3363
Stepdown2	21.9127	0.4672	1.1798	2.4481
p-value	0.0000	0.4966	0.2813	0.1224

7. Conclusions

7. Conclusions

7.1 Summary of results

In this paper, we examined the contention that focusing on "listed infrastructure" has the potential to create diversification benefits previously unavailable to large investors already active in public markets. The reasons for doing so were threefold:

1. Several papers have argued that it is the case but do not provide robust statistical tests of this hypothesis;
2. Index providers have created dedicated indices focusing on this theme and a number of active managers propose to invest in listed infrastructure arguing that it is an asset class in its own right;
3. Capital market instruments are often used by investors to proxy investments in privately-held (unlisted) infrastructure but the adequacy of such proxies remains untested.

We tested the notion that there is a unique and persistent "listed infrastructure effect" using 22 listed infrastructure proxies and a series of statistical tests of mean-variance spanning against reference portfolios, built with either traditional asset classes or investment factors. We conducted these tests for global, U.S. and UK markets covering the past 15 years, on a price return and total return basis.

We conclude that **listed infrastructure**, as it is traditionally defined by SIC code and industrial sector, **is not an asset class or a unique combination of market factors**, but instead cannot be persistently distinguished from existing exposures in investors' portfolios. Expecting the emergence of a new or unique "infrastructure asset class" by focusing on public equities selected on the basis of industrial sectors is thus misguided. Such asset selection schemes do not create diversification benefits. Figure 4 provides an illustration of these results in the case of the FTSE Macquarie Listed Infrastructure Index for the U.S. market.

Our test result are summarised in table 12. Stylised facts include:

1. We tested 22 proxies of listed infrastructure and found little to no robust evidence of a "listed infrastructure asset class" that was not already spanned by a combination of capital market instruments and alternatives or a factor-based asset allocation;
2. The majority of test portfolios that improved the mean-variance efficient frontier before the GFC fail to repeat this feat post GFC. There is no evidence of persistent diversification benefits;
3. Of the 22 test portfolios used in this paper to try and establish the existence of a listed infrastructure asset class, only four manage to improve on a typical asset allocation defined either by traditional asset class or by factor exposure after the GFC and only one is not spanned both pre- and post-GFC. We return to these in the discussion below;
4. Building baskets of stocks on the basis of their SIC code and proportion of infrastructure income fails generate a convincing exposure to a new asset class.

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Table 12: Summary table of mean-variance spanning tests: This table summarises the findings of the mean-variance spanning tests for the infrastructure proxies and different asset allocation strategies employed in this paper. ✓indicated that the infrastructure proxy passed all three spanning tests at the 5% confidence level either with reference to an asset class-build portfolio or a factor-built portfolio. The first column reports results for the whole sample from 2000 to 2014, the next two columns report pre- and post-GFC results and the fourth column highlights the proxies that show post-GFC persistence of pre-GFC improvement of the efficient portfolio frontier.

	Full sample	Pre-GFC	Post-GFC
Price Returns			
50% Rev. Req. Telecom.	×	×	×
50% Rev. Req. Transport	×	×	×
50% Rev. Req. Utilities	×	×	×
75% Rev. Req. Telecom.	×	×	×
75% Rev. Req. Transport	×	×	×
75% Rev. Req. Utilities	×	×	×
90% Rev. Req. Telecom.	×	×	×
90% Rev. Req. Transport	×	×	×
90% Rev. Req. Utilities	×	×	×
Alerian MLP	✓	×	×
FTSE Macquarie USA	×	×	×
MSCI USA	×	×	×
MSCI USA Infra Capped	×	×	×
DJ Brookfield Global	✓	×	✓
S&P Infrastructure	×	✓	×
FTSE Macquarie Infra	×	×	×
FTSE Global Core	×	×	×
MSCI World Infra	×	✓	×
MSCI ACWI Infra Capped	×	×	×
UBS Global Infra Uti	✓	✓	×
UBS Global 50-50	×	×	×
PFI Portfolio	×	×	×
Total Returns			
50% Rev. Req. Telecom.	×	×	×
50% Rev. Req. Transport	×	×	×
50% Rev. Req. Utilities	×	×	×
75% Rev. Req. Telecom.	×	×	×
75% Rev. Req. Transport	×	×	×
75% Rev. Req. Utilities	×	×	×
90% Rev. Req. Telecom.	×	×	×
90% Rev. Req. Transport	✓	×	×
90% Rev. Req. Utilities	×	×	×
Alerian MLP	×	×	✓
FTSE Macquarie USA	×	×	×
MSCI USA	×	×	×
MSCI USA Infra Capped	×	×	×
DJ Brookfield Global	✓	×	✓
FTSE Global Core	×	✓	×
S&P Infrastructure	✓	✓	×
FTSE Macquarie Infra	✓	✓	×
MSCI World Infra	×	✓	×
MSCI ACWI Infra Capped	✓	✓	✓
UBS Global Infra Uti	✓	✓	×
UBS Global 50-50	✓	×	×
PFI Portfolio	✓	×	✓

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A more promising avenue is to focus on underlying contractual or governance structures that tend to maximise dividend payout and pay dividends with great regularity, such as the PFI or MLP models;

5. More generally, benchmarking unlisted infrastructure investments with thematic (industry-based) stock indices is unlikely to be very helpful from a pure asset allocation perspective i.e. the latter do not exhibit a risk/return trade-off or *betas* that large investors did not have access to already.

7.2 Discussion

While we conclude from testing the impact of 22 proxies, that there is no convincing evidence of a listed infrastructure asset class, it is worthwhile examining the four proxies that manage to improve on the proposed reference asset allocation *after* the GFC.

Indeed, high pre-GFC Sharpe ratios that do not survive the 2008 credit crunch and lose all statistical significance in mean-variance spanning tests post-GFC do not make good candidates for an asset class or bundle of factors. However, proxies that pass the mean-variance tests since 2008 may at least open the possibility of a more persistent effect.

The four proxies that are *not* already spanned by our reference portfolios in the post GFC period questions are:

1. The Brookfield Dow Jones Infrastructure Index: on close examination, this index made a significant shift towards the oil and gas sector after the GFC and benefited from the significant rise of oil prices in the subsequent period. We note, without further investigation, that since 2014 and the collapse of global oil prices, it has experienced lacklustre performance. Hence, rather than an "infrastructure effect", this proxy may have been capturing a kind of "oil play";
2. The MSCI ACWI Infrastructure Capped: this proxy is the only one which passes the spanning tests both pre- and post-GFC. It is one of the few listed infrastructure indices which is not simply weighted by market capitalisation but is instead constrained to have a maximum of one third of its assets invested in Telecoms, one third in Utilities and another third in energy and transportation. Hence, it uses a very *ad hoc* weighing scheme, vaguely resembling equal weighting, which nevertheless improves on the market cap-weighted point of reference. Again, rather than an effect driven by a hypothetical "infrastructure asset class", it seems reasonable to assume that portfolio weights explain the impact of this proxy;[10]
3. The Alerian MLP Index: this proxy and the next one only improve the reference allocation post GFC in a total return basis. Here the role played by dividend payouts, their size and regularity relative to other stocks are likely candidates to explain why they succeed in passing the

10 - In future research, similar test of mean-variance spanning against efficient or "smart" reference indices is necessary to control for such effects.

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spanning tests. However, this index also proves to be high risk and correlated with the energy price cycle

4. The PFI Portfolio, because it corresponds to self-contained investment vehicles that receive a steady income stream from the public sector and have risky but predictable operating and financing costs, and are, by design, likely to have very regular dividend payouts.

This last point is important since the observed improvement of the efficient frontier by adding assets such as MLPs or PFIs also corresponds to the beginning of the very low interest rate policies introduced by U.S. and U.K. central banks after the GFC. In such an environment, such high-coupon paying assets start to exhibit previously unremarkable characteristics that, mechanically increases their ability to have an impact on the reference portfolio.

Crucially, what determines this ability to deliver regular and high dividend payouts is the contractual and governance structure of the underlying businesses, not their belonging to a given industrial sector, which does not suggest any particular *a priori* dividend paying behaviour.

However, it must be noted that the relatively low aggregate market capitalisation of listed entities offering a "clean" exposure to infrastructure "business models" as opposed to infrastructure industrial sectors may limit the ability of investors to enjoy these potential benefits unless the far larger *unlisted* infrastructure fund universe has similar characteristics.

We conclude that *as an asset selection scheme*, the notion of investing in "infrastructure" (listed or not) should be understood as a *heuristic* i.e. a mental shortcut meant to create an exposure to certain factors, but neither a thing nor an end in itself.

A clear distinction can be made between infrastructure as a matter of public policy, in which case the focus is rightly on industrial functions, and the point of view of financial investors, who may be exposed to completely different risks through investments in firms providing exactly the same industrial functions. Notional grouping of assets by industrial sectors (transport, energy, water, etc) create very little information or predictive power.

Focusing on definitions of infrastructure investment that match the tangible or industrial characteristics of certain firms or assets is unhelpful because it does not take in to account the mechanisms that create the potentially desirable characteristics of infrastructure investment. Infrastructure investment should be construed solely as a way to buy claims on future cash flows created by specific underlying business models, themselves the product of long-term contractual arrangements between public and private parties (or alternatively between two private parties).

8. Appendices

8. Appendices

Table 13: Descriptive statistics of annualised price and total returns of reference asset classes, 2000-2014

Panel A: Descriptive statistics of annualised price and total returns of the global reference asset classes, 2000-2014

Price Returns

	Bonds	Real Estate	Commo	Hedge Funds	OECD Stocks	EM Stocks
Price return	0.0545	0.0152	0.0224	0.0615	−0.0010	0.0162
Risk	0.0584	0.1998	0.2355	0.0568	0.1611	0.2339
SR	0.8445	0.0506	0.0734	0.9900	−0.0371	0.0478

Total Returns

	Bonds	Real Estate	Commo	Hedge Funds	OECD Stocks	EM Stocks
Tot. return	0.0545	0.0543	−0.0193	0.0634	0.0227	0.0436
Risk	0.0584	0.1993	0.2389	0.0567	0.1611	0.2336
SR	0.8446	0.2462	−0.1014	1.0253	0.1093	0.1645

Panel B: Descriptive statistics of annualised price and total returns of U.S. reference assets classes, 2000-2014

Price Returns

	Gov Bonds	Corp. Bonds	High Yld	Real Estate	Commo.	H. Funds	U.S. Stocks	World ex-U.S.
Price return	0.0132	0.0109	−0.0062	0.0634	0.0104	0.0645	0.0293	0.0038
Risk	0.0412	0.0344	0.0984	0.0567	0.2340	0.2186	0.1565	0.1739
SR	0.1973	0.1701	−0.1130	1.0255	0.0227	0.2710	0.1546	−0.0072

Total Returns

	Gov Bonds	Corp. Bonds	High Yld	Real Estate	Commo.	H.Funds	U.S. Stocks	World ex-U.S.
Tot. return	0.0545	0.0578	0.0806	0.0653	0.0104	0.1192	0.0482	0.0325
Risk	0.0419	0.0350	0.0996	0.0566	0.2340	0.2195	0.1566	0.1743
SR	1.1778	1.4997	0.7554	1.0597	0.0227	0.5179	0.2743	0.1568

Panel C: Descriptive statistics of annualised price and total returns of the U.K. reference asset classes, 2000-2014

Price Returns

	Fixed Interest	Real Estate	Commo.	H. Funds	UK. Stocks	World ex-UK
Price return	0.0590	0.0305	0.0487	0.0126	−0.0036	0.0201
Risk	0.0500	0.2074	0.1206	0.2171	0.1420	0.1548
SR	1.0755	0.1224	0.3605	0.0347	−0.0603	0.0971

Total Returns

	Fixed Interest	Real Estate	Commo.	H. Funds	UK. Stocks	World ex-UK
Tot. return	0.0590	0.0657	0.0506	0.0126	0.0309	0.0429
Risk	0.0498	0.2084	0.1206	0.2171	0.1423	0.1553
SR	1.0778	0.2898	0.3759	0.0347	0.1809	0.2427

Table 14: Descriptive statistics of annualised price and total returns of the reference factors, 2000-2014

Panel A: Descriptive statistics of annualised price and total returns of the global reference factors, 2000-2014

Price Returns

	Eur Market	U.S. Market	Size	Value
Price return	−0.0344	−0.0105	0.0522	0.0250
Risk	0.1963	0.1562	0.0713	0.0949
SR	−0.1997	−0.0989	0.6587	0.2099

Total Returns

	Eur Market	U.S. Market	Size	Value	Term	Default
Tot. return	−0.0031	0.0084	0.0467	0.0421	0.0387	−0.0069
Risk	0.1962	0.1561	0.0717	0.0946	0.0758	0.2274
SR	−0.0413	0.0219	0.5786	0.3904	0.4422	−0.0522

Panel B: Descriptive statistics of annualised price and total returns of the U.S. reference factors, 2000-2014

Price Returns

	Market	Size	Value	Term	Default
Price return	0.0162	0.0271	0.0290	−0.0022	−0.0242
Risk	0.1587	0.1058	0.1143	0.0870	0.0680
SR	0.0698	0.2081	0.2089	−0.0819	−0.4284

Total Returns

	Market	Size	Value	Term	Default
Tot. return	0.0348	0.0216	0.0430	0.0551	0.0330
Risk	0.1586	0.1061	0.1144	0.0871	0.0679
SR	0.1867	0.1558	0.3305	0.5723	0.4109

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Table 15: List of project finance SPVs in the listed PFI portfolio

Project name	Sector	Investor	Country	Revenue Source
A249 Road	Roads	HICL	UK	Unitary Charge
A92 Road	Roads	HICL	UK	Unitary Charge
Abbotsford Hospital	Hospitals	JLIF	Canada	Unitary Charge
Abingdon -Thames Valley Police	Gov Services	INPP	UK	Unitary Charge
Addiewell Prison	Gov Services	HICL	UK	Unitary Charge
Alberta Schools	Gov Services	INPP	Canada	Unitary Charge
Allenby and Connaught PFI Project, UK	Gov Services	HICL	UK	Unitary Charge
Angel Trains	Hospitals	INPP	UK	Unitary Charge
Aquasure Victorian Desalination Project, Australia	Gov Services	HICL	Australia	Purchase agreement
Avon and Somerset Courts	Gov Services	JLIF	UK	Unitary Charge
Barking and Dagenham PFI SPV 1	education	INPP	UK	Unitary Charge
Barking and Havering Clinics	Hospitals	BBGI	UK	Unitary Charge
Barking and Dagenham Schools	education	HICL	UK	Unitary Charge
Barnet and Haringey Clinics	Hospitals	BBGI	UK	Unitary Charge
Barnet Hospital, UK	Hospitals	HICL	UK	Unitary Charge
Barnet Street Lighting	Gov Services	JLIF	UK	Unitary Charge
Barnsley PFI SPV 1	education	INPP, JLIF	UK	Unitary Charge
Barnsley PFI SPV 2	education	INPP	UK	Unitary Charge
Barnsley PFI SPV 3	education	INPP	UK	Unitary Charge
BBG Lakeside	Hospitals	INPP	UK	Unitary Charge
Bedford Schools	education	BBGI	UK	Unitary Charge
BeNEX	Rail Link	INPP	Germany	unknown
Bentilee Hub Community Centre	Gov Services	JLIF	UK	Unitary Charge
Bexley Schools	education	JLIF	UK	Unitary Charge
Bexley, Bromley, Greenwich 1	Hospitals	INPP	UK	Unitary Charge
Bexley, Bromley, Greenwich 2	Hospitals	INPP	UK	Unitary Charge
BHH Mt Vernon	Hospitals	INPP	UK	Unitary Charge
BHH Sudhury	Hospitals	INPP	UK	Unitary Charge
Birmingham and Solihull LIFT	Hospitals	HICL	UK	Unitary Charge
Birmingham Hospitals	Hospitals	HICL	UK	Unitary Charge
Birmingham PFI SPV 1	education	INPP	UK	Unitary Charge
Bishop Auckland Hospital, UK	Hospitals	HICL	UK	Unitary Charge
Bistol PFI SPV 1	education	INPP	UK	Unitary Charge
Blackburn PFI SPV 1	education	INPP, HICL	UK	Unitary Charge
Blackburn PFI SPV 2	education	INPP	UK	Unitary Charge
Blackpool Primary Care Facility	Hospitals	HICL	UK	Unitary Charge
BMBF	education	INPP	Germany	Unitary Charge
Boldon School	education	HICL	UK	Unitary Charge
Bradford BSF Phase 2	education	HICL,INPP	UK	Unitary Charge
Bradford PFI SPV 1	education	INPP	UK	Unitary Charge
Brent, Harrow, Hillingdon	Hospitals	INPP	UK	Unitary Charge
Brentwood Community Hospital	Hospitals	HICL	UK	Unitary Charge
Brescia Hospital	Hospitals	INPP	Portugal	Unitary Charge
Brighton Hospital, UK	Hospitals	HICL	UK	Unitary Charge
Bristol BSF	education	JLIF	UK	Unitary Charge
Bristol Fishponds and Hampton House	Hospitals	INPP	UK	Unitary Charge
Bristol Shirehampton and Whitchurch	Hospitals	INPP	UK	Unitary Charge
Brockley Social Housing PFI	Gov Services	JLIF	UK	Unitary Charge
Burg Prison	Gov Services	BBGI	Germany	Unitary Charge
Calderdale	education	INPP	UK	Unitary Charge
Cambridgeshire PFI SPV 1	education	INPP	UK	Unitary Charge
Camden Housing	Gov Services	JLIF	UK	Unitary Charge
Canning Town Social Housing PFI	Gov Services	JLIF	UK	Unitary Charge
Central Middlesex Hospital, UK	Hospitals	HICL	UK	Unitary Charge
Clackmannanshire Schools	education	BBGI	UK	Unitary Charge
Cleveland Police Station and HQ	Gov Services	JLIF	UK	Unitary Charge
Connect PFI	Roads	HICL	UK	Unitary Charge
Conwy Schools, UK	education	HICL	UK	Unitary Charge
Cork School of Music	education	HICL	Ireland	Unitary Charge
Coventry Schools	education	BBGI	UK	Unitary Charge
Croydon Schools	education	HICL	UK	Unitary Charge
Darlington Schools, UK	education	HICL	UK	Unitary Charge
Defence Sixth Form College, UK	education	HICL	UK	Unitary Charge
Derby City PFI SPV 1	education	INPP	UK	Unitary Charge
Derby Courts	Gov Services	INPP	UK	Unitary Charge
Derby Schools	education	INPP, HICL	UK	Unitary Charge
Derby Schools 2	education	INPP	UK	Unitary Charge
Derbyshire PFI SPV 1	education	INPP	UK	Unitary Charge
Diabolo (T2 and T3 and T5)	Rail Link	INPP	UK	unknown

source: annual reports

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Table 16: List of project finance SPVs in the listed PFI portfolio (continued)

Project name	Sector	Investor	Country	Revenue Source
Doncaster Mental Health	Hospitals	HICL	UK	Unitary Charge
Doncaster Schools	education	HICL	UK	Unitary Charge
Dorset Fire and Rescue	Gov Services	HICL	UK	Unitary Charge
Dublin Courts	Gov Services	INPP	Ireland	Unitary Charge
Dudley Brierly Hill	Hospitals	INPP	UK	Unitary Charge
Dudley Ridge Hill and Stourbridge	Hospitals	INPP	UK	Unitary Charge
Durham and Cleveland Police Tactical Training Centre	Gov Services	HICL	UK	Unitary Charge
Durham Courts	Gov Services	INPP	Canada	Unitary Charge
Durham PFI SPV 1	education	INPP	UK	Unitary Charge
Dutch High Speed Rail Link	Roads	HICL	Netherlands	Unitary Charge
E18 Motorway	Roads	BBGI	Norway	Unitary Charge
E18 Road	Roads	JLIF	Finland	Unitary Charge
Ealing Care Homes	Hospitals	HICL	UK	Unitary Charge
Ealing Schools, UK	education	HICL	UK	Unitary Charge
East Down Colleges	education	BBGI	UK	Unitary Charge
Ecole Centrale Supelec PPP Project, France	education	HICL	France	Unitary Charge
Edinburgh Schools	education	JLIF, HICL	UK	Unitary Charge
ELLAS	Hospitals	INPP	UK	Unitary Charge
ELLAS 2	Hospitals	INPP	UK	Unitary Charge
ELLAS 3	Hospitals	INPP	UK	Unitary Charge
ELLAS 4	Hospitals	INPP	UK	Unitary Charge
Enfield Schools	education	JLIF	UK	Unitary Charge
Enfield Street Lighting	Gov Services	JLIF	UK	Unitary Charge
Essex PFI SPV 1	education	INPP	UK	Unitary Charge
Essex PFI SPV 2	education	INPP	UK	Unitary Charge
Exeter Crown Court, UK	Gov Services	HICL	UK	Unitary Charge
Falkirk NPD Schools	education	HICL	UK	Unitary Charge
Fife Schools 2 PPP	education	HICL	UK	Unitary Charge
Fife Schools, UK	education	HICL	UK	Unitary Charge
Forth Valley Royal Hospital	Hospitals	JLIF	UK	Unitary Charge
Glasgow Hospital	Hospitals	HICL	UK	Unitary Charge
Glasgow Schools	education	JLIF	UK	Unitary Charge
Gloucester Fire and Rescue, UK	Gov Services	HICL	UK	Unitary Charge
Gloucester Royal Hospital	Hospitals	BBGI	UK	Unitary Charge
Golden Ears Bridge	Roads	BBGI	Canada	Unitary Charge
Goscote	Hospitals	INPP	UK	Unitary Charge
Greater Manchester Police Authority	Gov Services	HICL, JIIF	UK	Unitary Charge
Groningen Tax Office	Gov Services	JLIF	Netherlands	Unitary Charge
Harrow NRC	Hospitals	INPP	UK	Unitary Charge
Haverstock School, UK	education	HICL	UK	Unitary Charge
Health and Safety Executive (HSE) Merseyside Headquarters	Gov Services	HICL	UK	Unitary Charge
Health and Safety Laboratory, UK	education	HICL	UK	Unitary Charge
Helicopter Training Facility, UK	education	HICL	UK	Unitary Charge
Hereford and Worcester	Gov Services	INPP	UK	Unitary Charge
Highland School, Enfield	education	JLIF, HICL	UK	Unitary Charge
Home Office Headquarters, UK	Gov Services	HICL	UK	Unitary Charge
Irish Grouped Schools	education	HICL	Ireland	Unitary Charge
Islington I Housing	Gov Services	JLIF, INPP	UK	Unitary Charge
Islington II Housing	Gov Services	JLIF, INPP	UK	Unitary Charge
Kelowna and Vernon Hospitals	Hospitals	BBGI, JLIF	Canada	Unitary Charge
Kent PFI SPV 1	education	INPP, BBGI, HICL	UK	Unitary Charge
Kicking Horse Canyon	Roads	BBGI, HICL	Canada	Unitary Charge
Kingston Hospital	Hospitals	JLIF	UK	Unitary Charge
Kirklees Social Housing	Gov Services	JLIF	UK	Unitary Charge
Kromhout Barracks	Gov Services	JLIF	Netherlands	Unitary Charge
Lambeth Street Lighting	Gov Services	JLIF	UK	Unitary Charge
Lancashire PFI SPV 1	education	INPP	UK	Unitary Charge
Lancashire PFI SPV 2	education	INPP	UK	Unitary Charge
Lancashire PFI SPV 2A	education	INPP	UK	Unitary Charge
Lancashire PFI SPV 3	education	INPP	UK	Unitary Charge
Leeds Combined Secondary Schools	education	JLIF	UK	Unitary Charge
Lewisham Hospital	Hospitals	HICL	UK	Unitary Charge
Lewisham PFI SPV 1	education	INPP	UK	Unitary Charge
Lewisham PFI SPV 2	education	INPP	UK	Unitary Charge
Lewisham PFI SPV 3	education	INPP	UK	Unitary Charge
Lisburn College	education	BBGI	UK	Unitary Charge
Liverpool and Sefton Clinics	Hospitals	BBGI	UK	Unitary Charge
Liverpool Library	Gov Services	INPP	UK	Unitary Charge
Long Bay	Hospitals	INPP	Australia	Unitary Charge

source: annual reports

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Table 17: List of project finance SPVs in the listed PFI portfolio (continued)

Project name	Sector	Investor	Country	Revenue Source
LUL Connect	Roads	JLIF	UK	Unitary Charge
Luton PFI SPV 1	education	INPP	UK	Unitary Charge
M40 Motorway	Roads	JLIF	UK	Unitary Charge
M6/M74 Project	Roads	JLIF	UK	Unitary Charge
M80 DBFO	Roads	HICL,BBGI	UK	Unitary Charge
Maesteg	education	INPP	UK	Unitary Charge
Manchester School	education	HICL	UK	Unitary Charge
Manchester Street Lighting	Gov Services	JLIF	UK	Unitary Charge
Medway LIFT	Hospitals	HICL	UK	Unitary Charge
Medway Police	Gov Services	HICL	UK	Unitary Charge
Mersey Care Mental Health Hospital	Hospitals	BBGI	UK	Unitary Charge
Metropolitan Police Specialist Training Centre	Gov Services	HICL, JLIF	UK	Unitary Charge
Miles Platting Social Housing, UK	Gov Services	HICL, JLIF	UK	Unitary Charge
Ministry of Defence Main Building	Gov Services	JLIF	UK	Unitary Charge
Moray Schools	education	INPP	UK	Unitary Charge
N17/18 Road, Ireland	Roads	HICL	Ireland	Unitary Charge
Newcastle Hospital	Hospitals	JLIF	UK	Unitary Charge
Newcastle Libraries	education	HICL	UK	Unitary Charge
Newham Hospital	Hospitals	JLIF	UK	Unitary Charge
Newham Schools	education	JLIF, INPP	UK	Unitary Charge
Newport Schools	education	HICL	UK	Unitary Charge
Newton Abbot Hospital	Hospitals	HICL	UK	Unitary Charge
Norfolk	Gov Services	INPP	UK	Unitary Charge
North East Fire and Rescue	Gov Services	JLIF	UK	Unitary Charge
North Staffordshire Hospital	Hospitals	JLIF	UK	Unitary Charge
North Swindon Schools	education	JLIF	UK	Unitary Charge
North Tyneside Schools, UK	education	HICL	UK	Unitary Charge
North Wales Police Authority	Gov Services	INPP	UK	Unitary Charge
Northampton Mental Health	Hospitals	JLIF	UK	Unitary Charge
Northampton Schools	education	INPP	UK	Unitary Charge
Northeast Stoney Trail	Roads	BBGI	Canada	Unitary Charge
Northwest Anthony Henday Ring Road P3	Roads	HICL, BBGI	Canada	Unitary Charge
Northwood MoD HQ	Gov Services	HICL	UK	Unitary Charge
Norwich Area Schools PFI Project	education	HICL	UK	Unitary Charge
Nottingham PFI SPV 1	education	INPP	UK	Unitary Charge
Nottingham PFI SPV 2	education	INPP	UK	Unitary Charge
NSW Schools	education	INPP	Australia	Unitary Charge
Nuffield Hospital	Hospitals	HICL	UK	Unitary Charge
Oldham Library	education	HICL	UK	Unitary Charge
Oldham Secondary Schools PFI Project	education	HICL	UK	Unitary Charge
Orange Hospital	Hospitals	INPP	Australia	Unitary Charge
Oxford Churchill Oncology	Hospitals	HICL	UK	Unitary Charge
Oxford Dunnock Way and East Oxford	Hospitals	INPP	UK	Unitary Charge
Oxford John Radcliffe PFI Hospital	Hospitals	HICL	UK	Unitary Charge
Pembury Hospital	Hospitals	JLIF	UK	Unitary Charge
Perth and Kinross Schools	education	HICL	UK	Unitary Charge
Peterborough Hospital	Hospitals	JLIF	UK	Unitary Charge
Peterborough Schools	education	JLIF	UK	Unitary Charge
Pforzheim Schools	education	INPP	UK	Unitary Charge
Pinderfields and Pontefract Hospitals, UK	Hospitals	HICL	UK	Unitary Charge
QFTO - Barrow	Renewables	INPP	UK	unknown
QFTO - Gunfleet Sands	Renewables	INPP	UK	unknown
QFTO - Lincs	Renewables	INPP	UK	unknown
QFTO - Ormonde	Renewables	INPP	UK	unknown
QFTO -Robin Rigg	Renewables	INPP	UK	unknown
Queen Alexandra Hospital, Portsmouth, UK	Hospitals	HICL	UK	Unitary Charge
Queen Elizabeth Hospital	Hospitals	JLIF	UK	Unitary Charge
Queen's (Romford) PFI Hospital	Hospitals	HICL	UK	Unitary Charge
RD901 Road, France	Roads	HICL	France	Unitary Charge
Realise Health (LIFT) Colchester	Hospitals	JLIF	UK	Unitary Charge
Redbridge and Waltham Forest LIFT	Hospitals	HICL	UK	Unitary Charge
Redcar and Cleveland Street Lighting	Gov Services	JLIF	UK	Unitary Charge
Reliance Rail	Rail Link	INPP	Australia	unknown
Renfrewshire Schools, UK	education	HICL	UK	Unitary Charge
Rhonnda Cynon Taf Schools	education	HICL	UK	Unitary Charge
Roseberry Park Hospital	Hospitals	JLIF	UK	Unitary Charge
Royal Children's Hospital	Hospitals	INPP	Australia	Unitary Charge
Royal School of Military Engineering PPP Project, UK	Gov Services	HICL	UK	Unitary Charge
Royal Women's Hospital	Hospitals	BBGI	Australia	Unitary Charge

source: annual reports

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Table 18: List of project finance SPVs in the listed PFI portfolio (end)

Project name	Sector	Investor	Country	Revenue Source
Royal Women's Hospital	Hospitals	BBGI	Australia	Unitary Charge
Salford and Wigan BSF Phase 1	education	HICL, INPP	UK	Unitary Charge
Salford and Wigan BSF Phase 2	education	HICL, INPP	UK	Unitary Charge
Salford Hospital, UK	Hospitals	HICL	UK	Unitary Charge
Scottish Borders Schools	education	BBGI	UK	Unitary Charge
Sheffield BSF, UK	education	HICL	UK	Unitary Charge
Sheffield Hospital, UK	Hospitals	HICL	UK	Unitary Charge
Sheffield Schools	education	HICL	UK	Unitary Charge
Showgrounds	Gov Services	INPP	Australia	Unitary Charge
Sirhowy Way	Roads	JLIF	UK	Unitary Charge
Somerset PFI SPV 1	education	INPP	UK	Unitary Charge
South Ayrshire Schools, UK	education	HICL	UK	Unitary Charge
South Bristol Community Hospital	Hospitals	INPP	UK	Unitary Charge
South East London Police stations	Gov Services	HICL, JLIF	UK	Unitary Charge
South Lanarkshire Schools	education	JLIF	UK	Unitary Charge
South West Hospital, Enniskillen	Hospitals	HICL	UK	Unitary Charge
Southwark PFI SPV 1	education	INPP	UK	Unitary Charge
Southwark PFI SPV 2	education	INPP	UK	Unitary Charge
St Thomas More School	education	INPP	UK	Unitary Charge
Staffordshire LIFT	Hospitals	HICL	UK	Unitary Charge
STaG PFI SPV 1	education	INPP	UK	Unitary Charge
STaG PFI SPV 2	education	INPP	UK	Unitary Charge
Stoke Mandeville Hospital, UK	Hospitals	HICL	UK	Unitary Charge
Stoke on Trent and Staffordshire Fire and Rescue Service	Gov Services	BBGI	UK	Unitary Charge
Strathclyde	Gov Services	INPP	UK	Unitary Charge
Surrey Street Lighting	Gov Services	JLIF	UK	Unitary Charge
Sussex Custodial Services, UK	Gov Services	HICL	UK	Unitary Charge
Tameside General Hospital	Hospitals	HICL	UK	Unitary Charge
Tameside PFI SPV 1	education	INPP	UK	Unitary Charge
Tameside PFI SPV 2	education	INPP	UK	Unitary Charge
Tor Bank School	education	BBGI	UK	Unitary Charge
Tower Hamlets Schools	education	INPP	UK	Unitary Charge
Tyne and Wear Fire Stations	Gov Services	HICL	UK	Unitary Charge
University of Bourgogne, France	education	HICL	UK	Unitary Charge
University of Sheffield Project, UK	Education	HICL	UK	Unitary Charge
Unna Administrative Centre	Gov Services	BBGI	Germany	Unitary Charge
Vancouver General Hospital	Hospitals	JLIF	Canada	Unitary Charge
Victoria Prisons	Gov Services	BBGI	Australia	Unitary Charge
Wakefield Street Lighting	Gov Services	JLIF	UK	Unitary Charge
Walsall Street Lighting	Gov Services	JLIF	UK	Unitary Charge
Waltham Forest PFI SPV 1	education	INPP	UK	Unitary Charge
West Lothian Schools	education	HICL	UK	Unitary Charge
West Middlesex Hospital, UK	Hospitals	HICL	UK	Unitary Charge
Willesden Hospital	Hospitals	HICL	UK	Unitary Charge
Wolvehampton PFI SPV 1	education	INPP	UK	Unitary Charge
Wolverhampton and Walsall	Hospitals	INPP	UK	Unitary Charge
Wolverhampton PFI SPV 2	education	INPP	UK	Unitary Charge
Women's College Hospital	Hospitals	BBGI	Canada	Unitary Charge
Wooldale Centre for Learning, UK	education	HICL	UK	Unitary Charge
Zaanstad Penitentiary Institution, The Netherlands	Gov Services	HICL	Netherlands	Unitary Charge

source: annual reports

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About the EDHEC Infrastructure Institute-Singapore

About the EDHEC Infrastructure Institute-Singapore

EDHEC*infra* addresses the profound knowledge gap faced by infrastructure investors by collecting and standardising private investment and cash flow data and running state-of-the-art asset pricing and risk models to create the performance benchmarks that are needed for asset allocation, prudential regulation and the design of new infrastructure investment solutions.

A Profound Knowledge Gap

Institutional investors have set their sights on private investment in infrastructure equity and debt as a potential avenue towards better diversification, improved liability-hedging and reduced drawdown risk.

Capturing these benefits, however, requires answering a number of difficult questions:

1. **Risk-adjusted performance measures** are needed to inform strategic asset allocation decisions and monitoring performance;
2. **Duration and inflation hedging properties** are required to understand the liability-friendliness of infrastructure assets;
3. **Extreme risk measures** are in demand from prudential regulators amongst others.

Today none of these metrics is documented in a robust manner, if at all, for investors in privately-held infrastructure equity or debt. This has left investors frustrated by an apparent lack of adequate investment solutions in infrastructure. At the same time, policy-makers have begun calling for a widespread effort to channel long-term savings into capital projects that could support long-term growth.

To fill this knowledge gap, EDHEC has launched a new research platform, EDHEC*infra*, to collect, standardise and produce investment performance data for infrastructure equity and debt investors.

Mission Statement

Our objective is the creation a global repository of financial knowledge and investment benchmarks about infrastructure equity and debt investment, with a focus on delivering useful applied research in finance for investors in infrastructure.

We aim to deliver the best available estimates of financial performance and risks of reference portfolios of privately-held infrastructure investments, and to provide investors with important insights about their strategic asset allocation choices to infrastructure, as well as support the adequate calibration of the relevant prudential frameworks.

We are developing unparalleled access to the financial data of infrastructure projects and firms, especially private data that is either unavailable to market participants or cumbersome and difficult to collect and aggregate.

We also bring advanced asset pricing and risk measurement technology designed to answer investors' information needs about long-term investment in privately-held infrastructure, from asset allocation to prudential regulation and performance attribution and monitoring.

What We Do

The EDHECinfra team is focused on three key tasks:

1. **Data collection and analysis**: we collect, clean and analyse the private infrastructure investment data of the project's data contributors as well as from other sources, and input it into EDHECinfra's unique database of infrastructure equity and debt investments and cash flows. We also develop data collection and reporting standards that can be used to make data collection

About the EDHEC Infrastructure Institute-Singapore

more efficient and reporting more transparent.
This database already covers 15 years of data and hundreds of investments and, as such, is already the largest dedicated database of infrastructure investment information available.

2. **Cash flow and discount rate models**: Using this extensive and growing database, we implement and continue to develop the technology developed at EDHEC-Risk Institute to model the cash flow and discount rate dynamics of private infrastructure equity and debt investments and derive a series of risk and performance measures that can actually help answer the questions that matter for investors.

3. **Building reference portfolios of infrastructure investments**: Using the performance results from our asset pricing and risk models, we can report the portfolio-level performance of groups of infrastructure equity or debt investments using categorisations (e.g. greenfield vs brownfield) that are most relevant for investors' investment decisions.

Partners of EDHEC*infra*

Monetary Authority of Singapore

In October 2015, the Deputy Prime Minister of Singapore, Tharman Shanmugaratnam, announced officially at the World Bank Infrastructure Summit that EDHEC would work in Singapore to create "usable benchmarks for infrastructure investors."

The Monetary Authority of Singapore is supporting the work of the EDHEC Singapore Infrastructure Investment Institute (EDHEC infra) with a five-year research development grant.

Sponsored Research Chairs

Since 2012, private sector sponsors have been supporting research on infrastructure investment at EDHEC with several research Chairs that are now under the EDHEC Infrastructure Investment Institute:

1. The EDHEC/NATIXIS Research Chair on the Investment and Governance Characteristics of Infrastructure Debt Instruments, 2012-2015
2. The EDHEC/Meridiam/Campbell Lutyens Research Chair on Infrastructure Equity Investment Management and Benchmarking, 2013-2016
3. The EDHEC/NATIXIS Research Chair on Infrastructure Debt Benchmarking, 2015-2018
4. The EDHEC/Long-Term Infrastructure Investor Association Research Chair on Infrastructure Equity Benchmarking, 2016-2019
5. The EDHEC/Global Infrastructure Hub Survey of Infrastructure Investors' Perceptions and Expectations, 2016

Partner Organisations

As well as our Research Chair Sponsors, numerous organisation have already recognised the value of this project and have joined or are committed to join the data collection effort. They include:

- The European Investment Bank;
- The World Bank Group;
- The European Bank for Reconstruction and Development;
- The members of the Long-Term Infrastructure Investor Association;

About the EDHEC Infrastructure Institute-Singapore

- Over 20 other North American, European and Australasian investors and infrastructure managers.

EDHEC*infra* is also :

- A member of the Advisory Council of the World Bank's Global Infrastructure Facility
- An honorary member of the Long-term Infrastructure Investor Association

Origins and Recent Achievements

In 2012, EDHEC-Risk Institute created a thematic research program on infrastructure investment and established two Research Chairs dedicated to long-term investment in infrastructure equity and debt, respectively, with the active support of the private sector.

Since then, infrastructure investment research at EDHEC has led to more than 20 academic publications and as many trade press articles, a book on infrastructure asset valuation, more than 30 industry and academic presentations, more than 200 mentions in the press and the creation of an executive course on infrastructure investment and benchmarking.

Testament to the quality of its contributions to this debate, EDHEC infra's research team has been regularly invited to contribute to high-level fora on the subject, including G20 meetings.

Likewise, active contributions were made to the regulatory debate, in particular directly supporting the adaptation of the Solvency-2 framework to long-term investments in infrastructure.

This work has contributed to growing the limited stock of investment knowledge in the infrastructure space.

Significant **empirical findings** already include:

- The first empirical estimates of construction risk for equity and debt investors in infrastructure project finance;
- The only empirical tests of the statistical determinants of credit spreads in infrastructure debt since 2008, allowing controlling for the impact of market liquidity and isolating underlying risk factors;
- The first empirical evidence of the diversification benefits of investing in greenfield and brownfield assets, driven by the dynamic risk and correlation profile of infrastructure investments over their lifecycle;
- The first empirical documentation of the relationship between debt service cover ratios, distance to default and expected default frequencies;
- The first measures of the impact of embedded options in senior infrastructure debt on expected recovery, extreme risk and duration measures;
- The first empirically documented study of cash flow volatility and correlations in underlying infrastructure investment using a large sample of collected data covering the past fifteen years.

Key **methodological advances** include:

About the EDHEC Infrastructure Institute-Singapore

- A series of Bayesian approaches to modelling cash flows in long-term investment projects including predicting the trajectory of key cash flow ratios in a mean/variance plane;

- The first fully-fledged structural credit risk model of infrastructure project finance debt;

- A robust framework to extract the term structure of expected returns (discount rates) in private infrastructure investments using conditional volatility and initial investment values to filter implied required returns and their range at one point in time across heterogenous investors.

Recent **contributions to the regulatory debate** include:

- A parsimonious data collection template to develop a global database of infrastructure project cash flows;

- Empirical contributions to adapt prudential regulation for long-term investors.

Infrastructure Research Publications at EDHEC

Infrastructure Research Publications at EDHEC

EDHEC Publications

- Blanc-Brude, F., T. Whittaker and M. Hasan. Cash Flow Dynamics of Private Infrastructure Debt (March 2016).
- Blanc-Brude, F., T. Whittaker and M. Hasan. Revenues and Dividend Payouts in Privately-Held Infrastructure Investments (March 2016).
- Blanc-Brude, F., and M. Hasan. The Valuation of Privately-Held Infrastructure Equity Investments (January 2015).
- Blanc-Brude, F., M. Hasan and O.R.H. Ismail. Performance and Valuation of Private Infrastructure Debt (July 2014).
- Blanc-Brude, F., Benchmarking Long-Term Investment in Infrastructure (June 2014).
- Blanc-Brude, F., and D. Makovsek. How Much Construction Risk do Sponsors take in Project Finance. (August 2014).
- Blanc-Brude, F. and O.R.H. Ismail. Who is afraid of construction risk? (March 2013)
- Blanc-Brude, F. Towards efficient benchmarks for infrastructure equity investments (January 2013).
- Blanc-Brude, F. Pension fund investment in social infrastructure (February 2012).

Books

- Blanc-Brude, F. and M. Hasan, Valuation and Financial Performance of Privately-Held Infrastructure Investments. London: PEI Media, Mar. 2015.

Peer-Reviewed Publications

- F. Blanc-Brude, S. Wilde, and T. Witthaker, "Looking for an infrastructure asset class Definition and mean-variance spanning of listed infrastructure equity proxies", 2016 (*forthcoming*)
- Blanc-Brude, F., M. Hasan, and T. Witthaker, "Benchmarking Infrastructure Project Finance - Objectives, Roadmap and Recent Progress", Journal of Alternative Investments, 2016 (*forthcoming*)
- R. Bianchi, M. Drew, E. Roca and T. Whittaker, "Risk factors in Australian bond returns", Accounting & Finance, 2015

Infrastructure Research Publications at EDHEC

- Blanc-Brude, F. "Long-term investment in infrastructure and the demand for benchmarks," JASSA The Finsia Journal of Applied Finance, vol. 3, pp. 57–65, 2014.
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- Blanc-Brude, F. , H. Goldsmith, and T. Valila, "A comparison of construction contract prices for tradition- ally procured roads and public–private partnerships," Review of Industrial Organization, vol. 35, no. 1-2, pp. 19–40, 2009, ISSN: 0889-938X. DOI: 10.1007/s11151-009-9224-1.
- Blanc-Brude, F. , H. Goldsmith, and T. Valila, "Public-private partnerships in europe: an update," EIB Economic & Financial Reports, p. 24, 2007.
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- Blanc-Brude, F. , H. Goldsmith, and T. Valila, "Ex ante construction costs in the european road sector: a comparison of public-private partnerships and traditional public procurement," EIB Economic & Financial Reports, vol. 2006/1, 2006.
- O. Jensen and F. Blanc-Brude, "The handshake: why do governments and firms sign private sector participation deals? evidence from the water and sanitation sector in developing countries," World Bank Working Papers, Wold Bank Working Paper Series, no. October 2005, p. 25, 2006.

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