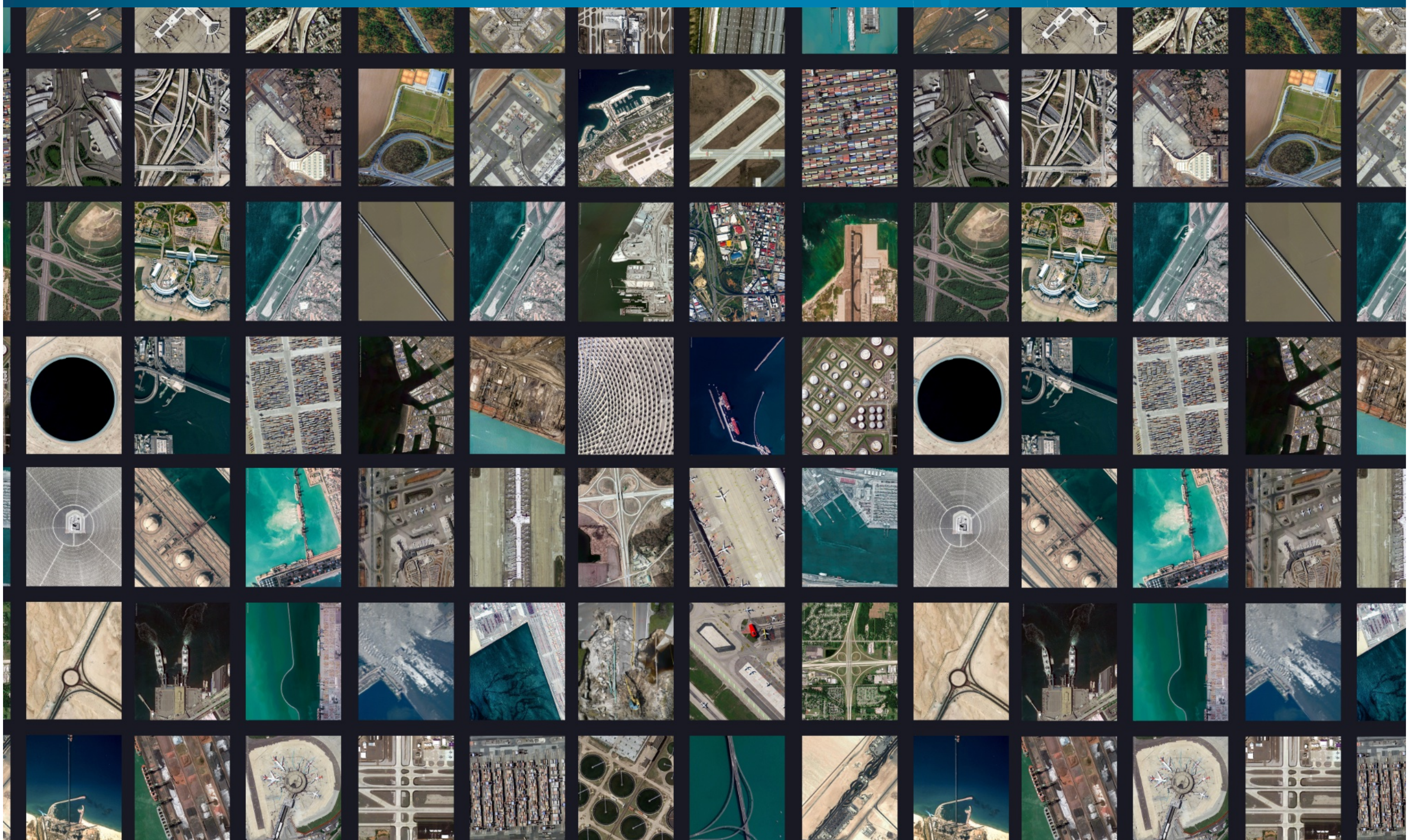
Achieving Diversification in Unlisted Infrastructure Investment

Smart Infra Portfolio Construction

March 2024



EDHEC Infrastructure & Private Assets Research Institute

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1. Executive Summary

In this paper, we examine two issues relevant to diversification and infrastructure investment: first, we look at portfolio construction and what it means to build a "well-diversified" portfolio of unlisted infrastructure equity; second, we turn to strategic asset allocation and examine the potential diversification benefits gained by adding infrastructure to the asset classes that make up a typical portfolio.

We know from previous research that the average investor in infrastructure holds, at any one time, between five and 25 infrastructure assets. Direct investors such as Canadian and Australian pension plans tend to have stakes in just a handful of assets, while fund managers typically offer access to a larger pool, especially when they offer multiple funds. Of course, fund of funds investors are exposed to a larger number of assets, sometimes hundreds.

However, is being exposed to many infrastructure assets sufficient to guarantee better diversification? Conversely, is a portfolio of just 10 infrastructure assets necessarily under-diversified? We show that answering these questions is not as simple as counting up the assets, sectors or countries in which individual investments have been made.

We show that the "naive" approach of adding more assets, sectors and geographies is a very inefficient and expensive way to build such a portfolio. In other words, diversifying an infrastructure portfolio can seem hard, maybe even impossible, if investors remains wedded to the "more is less" (more assets mean less risk) approach to diversification.

When investing in the infrastructure asset class as a whole is not practical or even possible, then any such investments may be better understood as active bets, justified by the selection and timing of individual infrastructure deals, than as an investment in a fully-fledged asset class that should be included in the strategy of a pension plan or insurer. However, we show that achieving a well-diversified portfolio of infrastructure investments actually is possible with a limited number of bets, as long as the key risk factors found in these investments are used to build the portfolio accordingly.

Using the intrinsic risk characteristics of infrastructure investments to build portfolios with high risk-factor exposures can achieve twice the diversification of the naïve approach with 10 times fewer assets. These 'smart' high-factor intensity infrastructure portfolios take advantage of the fact that risk factors are not only remunerated (earn a premium in the market) but are also independent (orthogonal) and thus diversify portfolio returns faster. In this case, "less is more" (fewer assets can achieve higher diversification).

This is an important finding, one which shows that it is possible for investors to build well-diversified and investible products that provide a genuine 'strategic' access to the asset class. While asset selection and timing are of course a source of manager alpha, being exposed randomly to a few assets leaves out systematic exposure to the desirable 'betas' that give infrastructure investment its genuine attractiveness as an asset class.

Next, assuming a well-diversified position in infrastructure equity, what are the implications of the imperfect correlations between unlisted infrastructure returns and other asset classes' in terms of strategic allocation? We show that, whatever the investor profile and portfolio optimisation objective, unlisted infrastructure equity can play a key role in the total portfolio, especially if it can be invested 'as an asset class' i.e., on a well-diversified basis, for example using the *Smart Infra* approach described in this paper.

The differences in return volatility and correlation between infrastructure and other classes, when measured correctly, suggest that in a portfolio of 10 asset classes including traditional and alternative investments, unlisted infrastructure should occupy a bucket typically ranging from 4.5% to 13% of the portfolio.

This research highlights an implementable approach to building better-diversified portfolios of infrastructure at a low cost and in a replicable manner across multiple funds or products. This is useful as it offers genuine access to the asset class to investors, including long-term retail or wealth management products. This approach does not try to be an active bet on a few infrastructure investments, however well-timed, selected or managed, but instead targets a clear and transparent exposure to the asset class.

2. Introduction

Long-term investors in infrastructure often present diversification as a key characteristic of their strategy. A recent survey of institutional investors by Andonov et al. (2021) confirms that they hold infrastructure investments for diversification purposes, despite the limited practicality of the strategy. Broad diversification can be challenging within this asset class: the lack of liquidity limits entries and exits, and thus complicates portfolio rebalancing. The inability to short sell in private markets also limits the scope of infrastructure investing to a long-only strategy.

In a recent paper, using the infra300 index as a proxy of the asset class, we showed that returns between infrastructure and capital markets are imperfectly correlated and also time varying especially at times of market shocks (see Blanc-Brude, 2022). Infrastructure investments can thus be expected to offer diversification benefits due to their market dynamics that are distinct from those of publicly-traded equities or fixed income securities.

While these results suggest that unlisted infrastructure equity offers a significant potential to improve total portfolio diversification, they also imply accessing the asset class *as such* - i.e. on a well-diversified basis. In practice, what does this mean for an investor in infrastructure? Is there a minimum number of assets or sectors that warrants using the phrase "well-diversified" in their annual report?

In this paper, we examine two issues relevant to diversification and infrastructure investment: first, we look at portfolio construction and what it means to build a "well-diversified" portfolio of unlisted infrastructure equity; second, we turn to strategic asset allocation and examine the potential diversification benefits gained by adding infrastructure to the asset classes that make up a typical portfolio.

We know from previous research that the average investor in infrastructure holds, at any one time, between five and 25 infrastructure assets (Amenc et al., 2023). Direct investors such as Canadian and Australian pension plans tend to have stakes in just a handful of assets, while fund managers typically offer access to a larger pool, especially when they offer multiple funds. Of course, fund of funds investors are exposed to a larger number of assets, sometimes hundreds.

However, is being exposed to many infrastructure assets sufficient to guarantee better diversification? Conversely, is a portfolio of just 10 infrastructure assets necessarily under-diversified? We show that answering these questions is not as simple as counting up the assets, sectors or countries in which individual investments have been made.

In effect, most investors simply cannot invest across numerous individual assets, sectors and geographies. Beyond the relatively small fund-of-infrastructure-funds segment and a few large LPs, direct investors and most investors in funds find themselves limited to a handful of infrastructure assets.

When investing in the infrastructure asset class as a whole is not practical or even possible, then any such investments may be better understood as active bets, justified by the selection and timing of individual infrastructure deals, than as an investment in a fully-fledged asset class that should be included in the strategy of a pension plan or insurer. However, we show that achieving a well-diversified portfolio of infrastructure investments actually is possible with a limited number of bets, as long as the key risk factors found in these investments are used to build the portfolio accordingly.

Next, assuming a well-diversified position in infrastructure equity, what are the implications of the imperfect correlations between unlisted infrastructure returns and other asset classes' in terms of strategic allocation?

According to Markowitz (1952) a risk averse investor can minimise their total portfolio risk for a given level of return, or maximise return for a given level of risk, through an efficient combination of assets. Although the portfolio variance can be reduced, it can never be eliminated due to common economic exposures, implying non-zero return covariance between investments. Over the last several decades, investors have been diversifying their portfolios by shifting away from classic stocks and bonds strategies and instead adding alternative asset classes to their portfolios, including unlisted infrastructure. Common economic exposures between infrastructure returns have become clear to see, between the impact of certain economic shocks on cash flows, investor demand on the infrastructure equity risk premium, and the yield curve on discount rates. Given these cross-asset class links, which we can now measure on monthly basis, how much infrastructure should investors hold in their portfolio alongside stock, bonds, and other private assets and alternatives?

The rest of this paper is structured as follows:

First (section 3), we use a dataset of unlisted infrastructure capital returns to examine the nature of portfolio diversification in unlisted infrastructure and discuss how this should guide portfolio construction.

We test four different ways to diversify a portfolio of infrastructure equity investments. The first three consist of 1/ adding more assets, 2/ adding more sectors (and assets) and 3/ adding more countries (and assets) to a portfolio. We label these three diversification strategies as "naïve" because they consist solely in the addition of assets to a portfolio without taking return covariance into consideration explicitly but instead assuming that assets, sectors and countries are not perfectly correlated and therefore that adding more of each to a portfolio should achieve higher diversification.

We show that this is the case but at a very high cost: achieving robust diversification requires investing in hundreds of assets across dozens of sectors and geographies i.e., it is not achievable in practice expect for a handful of funds of funds.

However, we propose an alternative fourth approach, which consists of using explicit risk factor exposures that have been shown to explain returns such as Size, Leverage, Profits, etc. to build portfolios using high 'factor intensity' assets. We show that a better level of diversification can be achieved with a handful of assets than with hundreds of them just as long as the portfolio is built to exploit the impact of each risk factor on asset returns.

Second (section 4, we examine the role of infrastructure investments, as proxied by high factor intensity index, in a multi-asset class portfolio. Differences in return volatility and correlation between infrastructure and other asset classes, as measured using infraMetrics data, capture the genuine volatility of the asset class. They suggest that in a portfolio of 10 asset classes, including traditional and alternative investments, unlisted infrastructure should occupy a bucket typically ranging from 4.5% to 13% of the portfolio.

3. Portfolio Construction: building a well-diversified infrastructure equity portfolio

To understand how one might build a well-diversified portfolio of infrastructure assets, it is useful to consider the fundamental mechanism by which diversification takes place: risks that exist at the asset-level only (specific or so-called idiosyncratic risks) can offset each other, precisely because they are independent from one other. Hence, with numerous assets, the average value of asset-specific risks should become small and could trend towards zero, at which point they would be considered fully diversified. Conversely, risks that are common to all assets can never be eliminated due to common economic exposures, implying non-zero return covariance between investments. In other words, risks that infrastructure investments have in common cannot be diversified away by investing in more assets, since these risks are present in all assets. They can however be invested more or less optimally.

While infrastructure investments are very heterogeneous and different from one another, it is important to recognise the existence of common risk factors in a portfolio of such investments.

Firstly, the infrastructure assets found in a given industry sector can actually be very similar: a series of wind farms in Europe, while exposed to different wind patterns and regulatory conditions, have a lot in common. In particular, they typically have a very similar type of corporate and financial structure, creating common exposures to the yield curve and refinancing risk, as well as a common (and often high) level of investor demand, implying increasing valuations (the equity risk premium) that apply to the value of all assets on a given date.

Moreover, infrastructure equity investments ultimately are investments in companies, albeit a specific kind of company (see Whittaker and Tan, 2019, for an empirical analysis) i.e., the factors that tend to make companies more or less risky and thus more or less valuable apply to these investments as well. For example, a more profitable infrastructure company is, *ceteris paribus*, more likely to pay dividends and thus has a higher value (a lower discount rate). This suggests that profitability is one of several proxies of dividend risk and therefore of the valuation of an infrastructure company. Since all infrastructure equity investments are exposed to this *profit factor*, this effect is systematic and not fully diversifiable. Instead, on a given date, the market is willing to pay a price (a risk premium) to be exposed to this risk, which is true for all assets in a portfolio. Research has shown that more such systematic risk factors exist in infrastructure investment, including size, term, investment, leverage, merchant or contracted business models, as well as sector effects. We return to these below.

Given this combination of systematic and idiosyncratic risks, how can investors build a well-diversified portfolio of infrastructure investments? In this section, we consider several strategies to diversify a portfolio invested in the unlisted infrastructure asset class only.

We first consider allocating capital across a range of assets, sectors, or geographies. These approaches reflect the way diversification is often presented by fund managers. We label them "naïve" diversification strategies because they rest on the simple assumption that "more is less" i.e., more assets, sectors, countries is less risk. The main characteristic of these approaches is their high cost: we show that achieving meaningful diversification through this approach is almost impossible to achieve, short of investing in hundreds of assets, probably through a fund of funds.

Next, we then look at strategies that make use of the known systematic risk exposures found in infrastructure investments to build "high factor intensity" portfolios that capture the rewarded characteristics of infrastructure investments better and show that "less is more' (fewer assets can lead to more diversification than the naïve strategies if they create the right risk factor exposures). This approach is identical in spirit to smart beta investing (we label it "smart infra") and, unlike naïve strategies, it is practical and replicable because it rests on investing in exposures to risk factors that are universally found in infrastructure companies.

The sample of infrastructure companies used to build our test portfolios includes the 800+ unlisted infrastructure companies tracked in infraMetrics®. This sample is designed to be representative of a global universe of 9,100+ unlisted infrastructure companies both in terms of geography and TICCS® segments i.e., business model, activity and corporate structure. We use price (capital) returns in USD.

3.1 Naïve Diversification Strategies

3.1.1 Approach

To represent a diversification strategy that would simply consist of adding more and more assets to a portfolio, we build hundreds of random portfolios for different target numbers of assets: we sample randomly from the 800+ assets in the infraMetrics database and produce 100 portfolios of five assets, 10 assets, 15 assets, etc. For each group by number of assets, we compute the average return, risk and Sharpe ratio for the 100 portfolios.

The Sharpe ratio is the risk-adjusted return of the portfolio (the excess return divided by the portfolio risk) and serves as a first diversification indicator in what follows. Indeed, the objective of diversification is the optimisation of the Sharpe ratio: to get the best return per unit of risk taken.

As well as casually observing differences in Sharpe ratios, we conduct statistical tests of the difference in variance (and therefore risk reduction) between strategies. To do this, we measure the mean-variance efficiency of diversification strategies using the Ehling and Ramos (2006) test.

Say that r is the return of a benchmark portfolio, for example the average return of 100 random portfolios, each including 100 assets, we write $E(r_t) = \beta$ and $Var(r_t) = v$, for $t \in [0, T]$.

Next, matrix R includes the returns on p test portfolios with $E(R_t) = \mu$, $Cov(R_t) = \Sigma$, and $Cov(R_t, r_t) = \gamma$. Our test portfolios include 25 assets, to represent the typical number of assets found in an infrastructure portfolio or fund.

Suppose that there is a mean-variance efficient combination of the test portfolios with a return r_t^β that equals the return of the benchmark portfolio, $E(r_t^\beta) = \beta$.

The measure of efficiency of the portfolio of test portfolios with respect to the benchmark is measured as the difference in their variances, $\lambda = Var(r_t^\beta) - v$.

To measure the efficiency for the portfolio of primitive assets, we use the Lagrangian method. The Lagrangian method provides a way to add several constraints such as no short selling and return matching in the portfolio optimisation problem. The following Lagrangian is solved:

$$\lambda = L = w'\Sigma w - v + \delta_1 \underbrace{(w'\bar{1} - 1)}_{\text{Equality Constraint}} + \delta_2 \underbrace{(w'\mu - \beta)}_{\text{Return Matching}} - \delta_3 \underbrace{w}_{\text{No Short Selling}}$$

where δ_1, δ_2 and δ_3 are the Lagrange multipliers of the restrictions.

The constraints we add to the Lagrangian are as follows:

- Portfolio weights constraints: Ensuring that the sum of the portfolio weights equal to 1, i.e. the capital is fully invested in the portfolio.
- Return matching constraints: Ensuring that the portfolio's expected return r_t^{β} equals to the return of the benchmark portfolio, $E(r_t^{\beta}) = \beta$.
- No short selling: As short selling is not permitted in unlisted infrastructure investments, this constraint should be added.

If λ is positive, the test portfolio has a higher variance than the benchmark and therefore it is not mean-variance efficient. Conversely, if λ is negative, then the test portfolio is efficient.

We apply the following test statistics under the null hypothesis $\lambda = 0$:

$$\xi = \frac{\sqrt{T}\lambda}{\lambda_\sigma},$$

where λ_σ is the standard deviation of the measure of efficiency. The test statistics is standard normally distributed for large values of T.

3.1.2 Diversification by number of assets

In this first case, we build 100 equally weighted random portfolios for each target number of constituents, from five to 100, irrespective of any other sector or geography criteria. This first strategy serve as a benchmark for comparing the effectiveness of more sophisticated diversification strategies that might consider correlations between sectors and geographies and exposure to specific risk factors.

Figure 1 shows the mean portfolio capital return variance and its range for 100 portfolios for each group of target number of constituents. It shows that fully reducing portfolio variance risk would, on average, require investing a very large number of assets (higher than 200, not shown on the chart). The typical 15 to 25 assets portfolio found in infrastructure funds, as long as it is invested randomly, is thus far from being "well-diversified."

Moreover, while the most substantial decrease in average risk occurs when the portfolio size increases to around 25 assets, the range of possible values (grey vertical lines) indicates that many 25-asset portfolios are just as volatile as 10-asset portfolios. While the average risk might appear lower with 25 assets, the actual risk profile may vary significantly depending on the homogeneity of the underlying assets. According to portfolio theory, adding a few assets to a very concentrated portfolio significantly reduces its risk. The initial reduction is due to the low or negative correlation between asset returns, which means that the price movements of these assets are not perfectly synchronised. As more assets are added to the portfolio, the marginal benefit of adding more assets is diminished as each additional asset diversifies away only a marginal amount of idiosyncratic risk.

Figure 2 shows the equivalent picture for the Sharpe ratio of each portfolio. Likewise, when the number of assets in a portfolio is small, the dispersion of the Sharpe ratio tends to be large, as illustrated by the wide 95% confidence interval due to high idiosyncratic risk. As the number of assets increases, the confidence interval narrows, indicating that the dispersion of the Sharpe ratio decreases. This suggests that the predictability of the portfolio's performance improves with more assets, as idiosyncratic risks are diversified away. With 100 assets, the Sharpe ratio confi-

Figure 1: Average volatility of 100 random portfolios for the naïve diversification by number of assets. The error bars represent the 95% confidence interval for the risk in the portfolio simulations. Calculations are in USD.

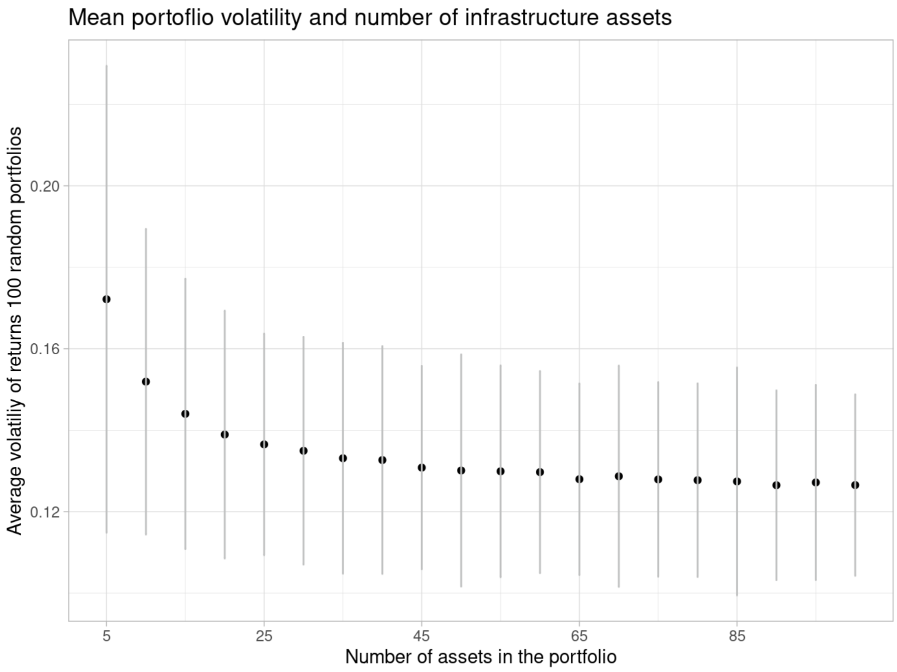


Figure 2: Average Sharpe ratio of 100 random portfolios for the naïve diversification by number of assets. The error bars represent the 95% confidence interval for the Sharpe ratios in the portfolio simulations. Calculations are in USD.

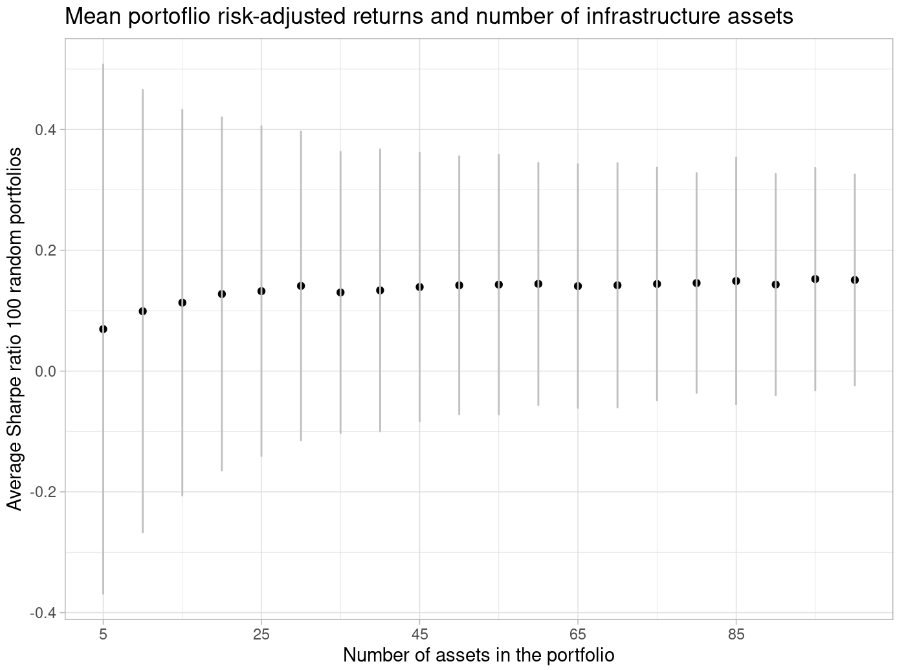


Table 1: Mean-variance efficiency test. λ is the Lagrangian problem, the test statistic is under the null hypothesis that $\lambda = 0$. The benchmark is the average of 100 portfolios invested in 100 random assets.

	25 Assets Naive Strategy	25 assets & 12 Sectors	25 assets & 12 Countries	High Risk Factors Portfoli 25 Assets
λ	0.003	0.0001	0.002	-0.002
Test Statistic	2.21	0.13	10.09	-4.65

dence interval is much tighter (0.165 to 0.655), reflecting a more reliable risk-adjusted performance.

Table 1, first column, shows the mean-variance efficiency test for the average 25-asset portfolio invested randomly, and finds that this *not* mean-variance efficient i.e., the 25-asset portfolio has higher variance than the benchmark variance, which was expected.

In conclusion, investing randomly in infrastructure assets allows some diversification as the number of portfolio constituents increases but the outcome remain very variable and requires investing in hundreds of assets to be effective.

3.1.3 Diversification by number of sectors and countries

Of course, investing randomly in more and more assets without taking sectors or geography into consideration is not an ideal way to try and diversify a portfolio. Since infrastructure asset returns are more alike (and therefore correlated) within a sector or country than between sectors and countries, building portfolios that explicitly aim to achieve a minimum number of sectors or geographies can be expected to achieve better diversification results.

Thus, we build 100 equally weighted random portfolios, diversifying across an increasing number of sectors/countries, ranging from two sectors/countries to 12 different sectors/countries. As before, for each portfolio configuration, we calculate the average return, risk, and Sharpe ratio across the 100 portfolios. The primary objective of this strategy is to understand how diversification across different TICCS industrial sectors or geographies influences the overall risk and return profile of infrastructure investment portfolios. Looking at correlations between individual TICCS industrial classes in Table 2, we can observe that returns in each class are imperfectly correlated, indicating that diversification across infrastructure sectors is possible but may also reach a limit beyond a certain point.

We first compare the performance of portfolios diversified across two or 12 sectors.

Figure 3 shows that a greater number of sectors can lead to higher risk-adjusted returns for any given number of assets.

In other words, *on average* broadening sector exposure can enhance risk-adjusted returns across various portfolio sizes. Yet, this strategy encounters unique challenges in the context of private infrastructure investment, practical limitations persist and a given portfolio may be far from the average. The confidence interval suggests that the Sharpe ratio might vary significantly within each strategy and there is no guarantee that all portfolios including 12 sectors are more diversified than those including only two sectors. This is because many of the common factors that explain returns are not sector specific but instead arch back to the fundamentals of private companies: profits, size, leverage, etc.

Table 1, second column shows the mean-variance efficiency test: a portfolio of 25 randomly chosen assets across 12 different sectors is *not* mean-variance efficient i.e., it has higher variance than the benchmark portfolio of 100 randomly selected assets.

Table 2: Correlation Matrix for TICCS Superclass Industrial Sector Price Return

	Power	Environmental Services	Social	Energy & Water	Data	Transport	Renewables	Network & Utilities
Power	1.00	0.79	0.71	0.79	0.47	0.77	0.77	0.75
Environmental Services	0.79	1.00	0.68	0.69	0.56	0.78	0.79	0.72
Social	0.71	0.68	1.00	0.81	0.67	0.84	0.74	0.91
Energy & Water	0.79	0.69	0.81	1.00	0.61	0.84	0.79	0.83
Data	0.47	0.56	0.67	0.61	1.00	0.71	0.72	0.70
Transport	0.77	0.78	0.84	0.84	0.71	1.00	0.83	0.89
Renewables	0.77	0.79	0.74	0.79	0.72	0.83	1.00	0.75
Network & Utilities	0.75	0.72	0.91	0.83	0.70	0.89	0.75	1.00

Figure 3: Naïve diversification by sector, risk-adjusted return. The red and blue bars represent the 95% confidence interval for the Sharpe ratios in the simulations for the two and 12 sectors portfolios respectively. Calculations are in USD.

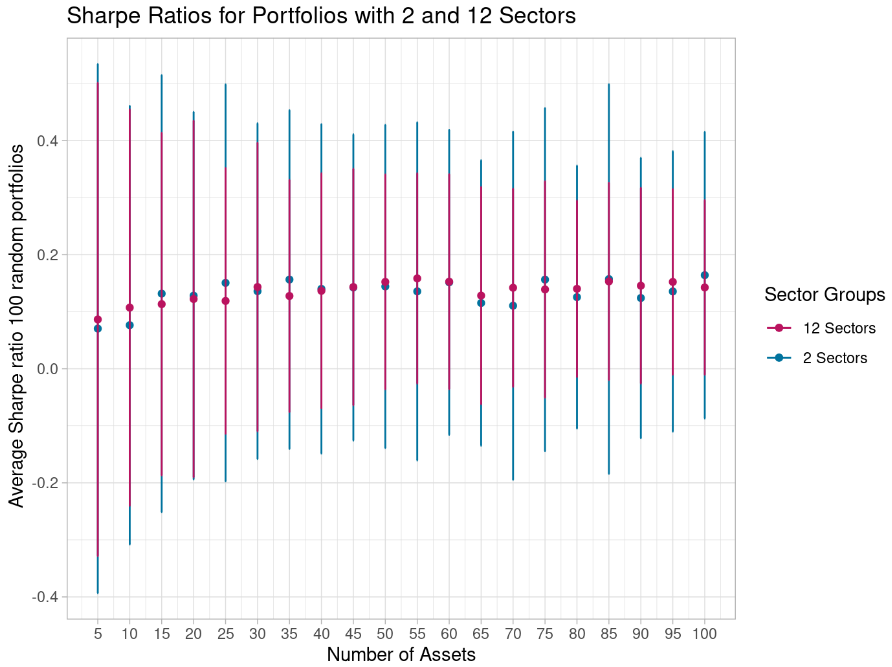


Figure 4: Naïve diversification by sector, risk-adjusted return. The red and blue bars represent the 95% confidence interval for the Sharpe ratios in the simulations for the two and 12 countries portfolios respectively. Calculations are in USD.

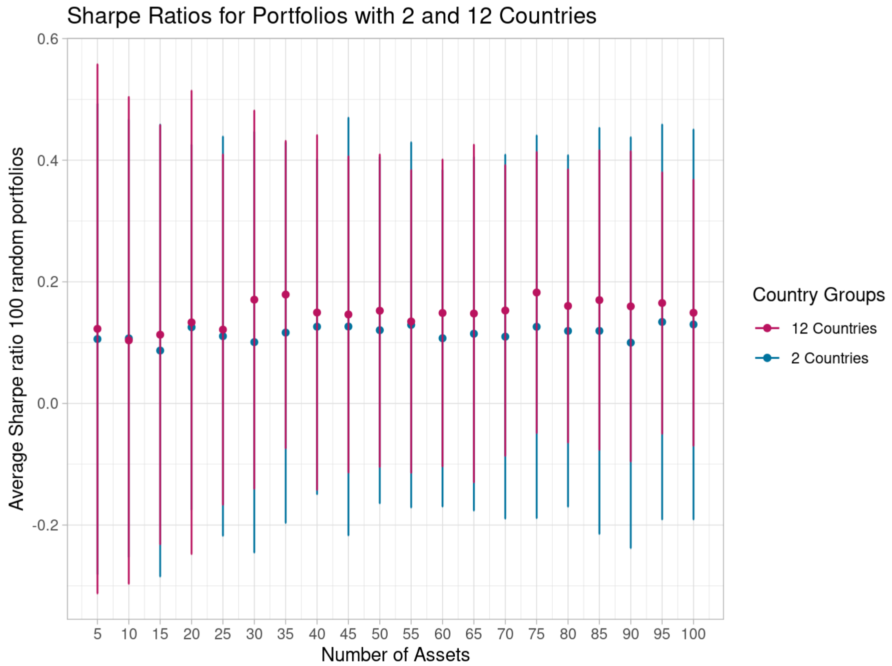


Table 3: Comparison between the three naive diversification strategies with 100 assets from 100 simulated portfolios and risk factors diversification based on 100 simulated portfolios of 25 assets. Results are in USD

	100 Assets Naive Strategy	100 assets & 12 Sectors	100 assets & 12 Countries	High Risk Factors Portfolio 25 Assets
Annualised Return	2.91%	2.78%	2.9%	7.6%
Annualised Risk	12.7%	12.5%	12.8%	18.5%
Sharpe Ratio [Up, Lo Bound]	0.151 [-0.023,0.325]	0.143 [-0.01,0.296]	0.149 [-0.07,0.368]	0.357 [0.173, 0.540]

Table 4: Comparison between the three naive diversification strategies with 100 assets from 100 simulated portfolios and risk factors diversification based on 100 simulated portfolios of 25 assets. Naive strategies are based on Value Weighting. Results are in USD.

	100 Assets Naive Strategy	100 assets & 12 Sectors	100 assets & 12 Countries	High Risk Factors Portfolio 25 Assets
Annualised Return	2.85%	2.8%	2.95%	7.6%
Annualised Risk	12.6%	12.6%	13%	18.5%
Sharpe Ratio [Up, Lo Bound]	0.146 [-0.029,0.321]	0.144 [-0.001,0.289]	0.150 [-0.085,0.385]	0.357 [0.173, 0.540]

Likewise, Figure 4 shows that diversifying across a range of countries, from two to 12, can yield higher risk-adjusted returns for any given number of assets, with the same caveat that this may be the case on average but not a guarantee for any given portfolio. Moreover, Table 1, third column shows that a portfolio of 25 randomly chosen assets across 12 different countries is *not* mean-variance efficient compared to the benchmark. In addition to this, managing investments across various countries introduces additional regulatory and forex complexity.

3.1.4 Robustness with Cap-Weighted Portfolio

So far we have used equally weighted portfolios to consider what the average portfolio with X assets and Y sectors or countries is like, and how dispersed the risk adjusted returns may be. As a further test of the above results, we consider using market value weighted portfolios instead. Value-weighted portfolios are more realistic. In effect, equally-weighted portfolios would require very impractical annual rebalancing. Value weighting, on the other hand, is closer to the realities of the market, where assets in a fund or portfolio have a weight corresponding to their market value or a proportion of it.

Figures 5 through 7 present the Sharpe ratios for each strategy using market value weights. Across all the scenarios, the improvements in the Sharpe ratios are very minimal, as well as the 95% confidence intervals are broader compared to those presented above portfolios. For instance, in figure 6 the broad confidence intervals illustrate great variability around the mean. This wider range highlights that fund managers may encounter significant fluctuations in Sharpe ratios regardless of the number of assets, sectors or countries. Furthermore, the analysis reveals that for portfolios formed based on sector diversification, the mean Sharpe ratio exhibits increased volatility with the inclusion of additional assets.

3.1.5 Is diversification even possible?

In summary, a fund manager investing in an infrastructure portfolio with a typical number of assets (25) is not likely to be diversified. The Sharpe ratio can vary greatly when the number of assets is low, as shown by the wider confidence interval. As more assets are added, the confidence interval narrows, suggesting a greater likelihood of being exposed to the average level of risk.

Instead, we have found that building a well-diversified portfolio of infrastructure equity investments represents a very high bar. As the number of assets in a portfolio increases substantially, the variance of a portfolio with equal investments in each stock aligns with the average covariance between assets returns

Figure 5: Average Sharpe ratio of 100 random Value Weighted portfolios for the naïve diversification by number of assets. The error bars represent the 95% confidence interval for the Sharpe ratios in the portfolio simulations.

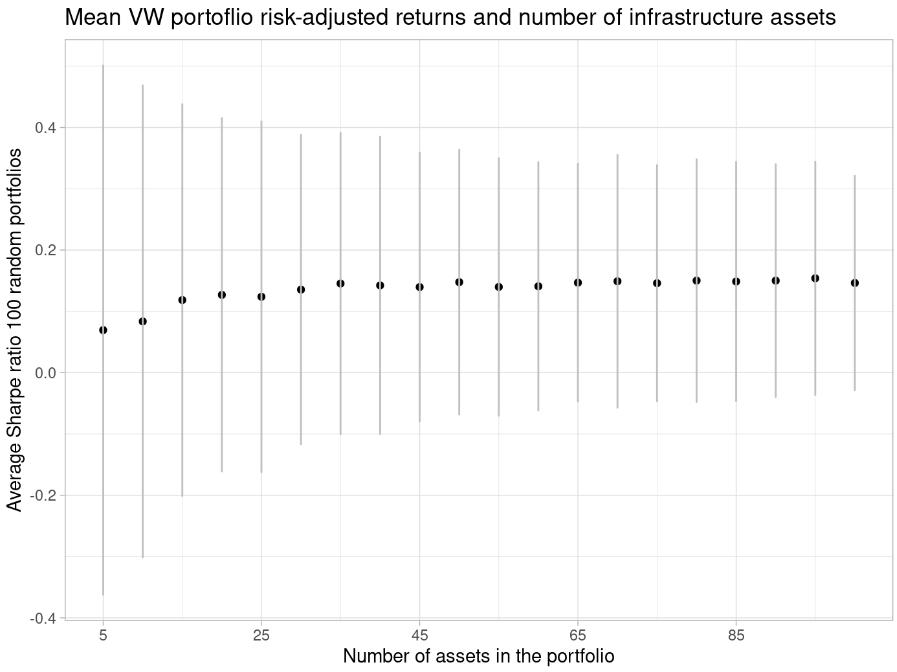


Figure 6: Naïve diversification by country, Value Weighted portfolios, risk-adjusted return. The red and blue bars represent the 95% confidence interval for the Sharpe ratios in the simulations for the two and 12 countries portfolios respectively.

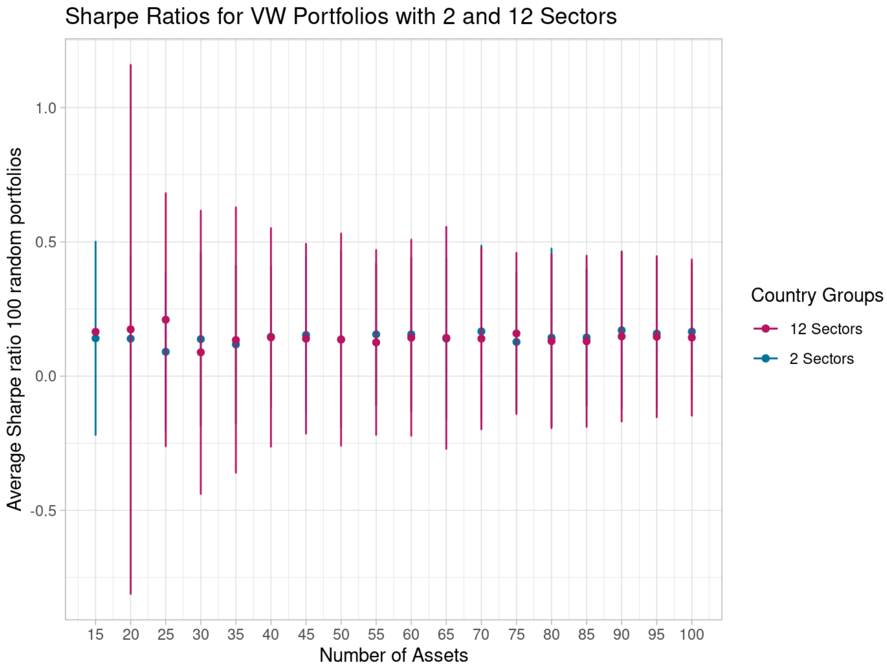
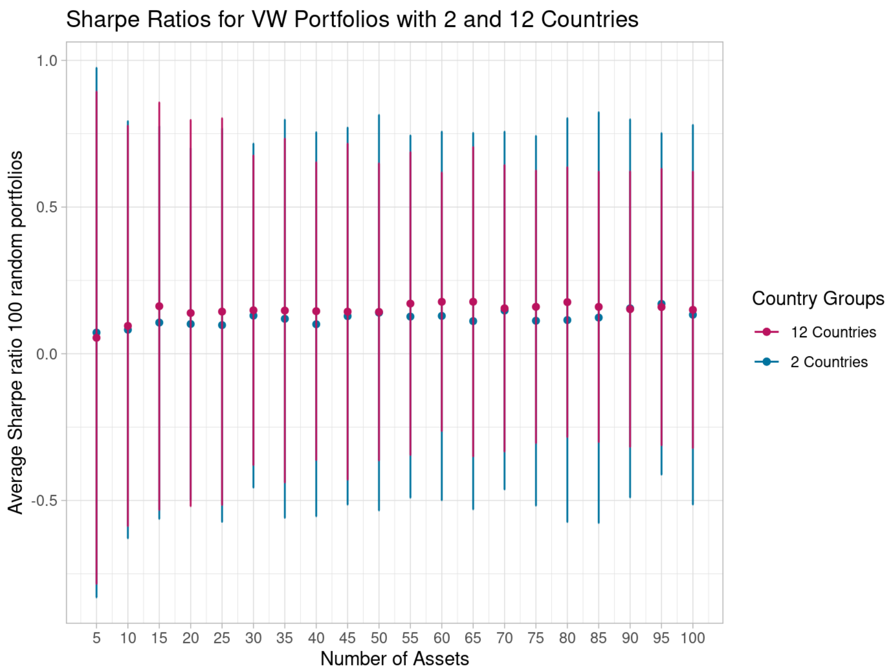


Figure 7: Naïve diversification by country, Value Weighted portfolios, risk-adjusted return. The red and blue bars represent the 95% confidence interval for the Sharpe ratios in the simulations for the two and 12 countries portfolios respectively.



(Markowitz, 1976). If portfolio risk can be reduced by increasing the number of assets, many private assets portfolios are constrained in size and holding a large number of assets is not possible.

Thus, if numerous assets are needed to be "well-diversified", achieving such a large portfolio can seem almost impossible for most. Infrastructure investors are also constrained by available capital, deal sizes, and the operational complexities of managing investments in a wide array of sector/countries. This means that achieving diversification in infrastructure is very expensive: either in terms of capital to deploy and transaction costs, or in terms of fees if investing via funds of funds. Indeed, major public and private pension funds in Europe, Canada, the US, and other regions tend to avoid funds-of-funds for infrastructure investments because of their higher investment cost (Carlo et al., 2023).

In the end, private infrastructure assets often represent an indivisible investment and constructing a portfolio with a large number of assets can be not only impractical but also financially unfeasible. Consequently, private infrastructure investors are typically restricted to holding a smaller number of assets.

This begs the question of the feasibility of diversification for infrastructure investors, which, in turns, conditions that of accessing the "asset class" instead of a few active bets. If a well-diversified infrastructure investment product cannot be built, then asset managers and direct investors offer access to a strategy resting on asset selection and deal timing. These are key sources of alpha, but not of a reliable set of infrastructure "betas". The latter are the key characteristics of the asset class such as cash flows stability, monopolistic business models, etc., all of which correspond to the average infrastructure asset, but are not necessarily found in a handful of infrastructure companies (since they are all very different!)

At this stage, an investor may give up on the asset class, focus on manager and investment selection, and consider infrastructure investments to be very active bets (which can still be benchmarked against the market, of course).

However, in what follows we propose an alternative approach, one that relies on the mechanism at the heart of the diversification process: the systematic risk factors found in all such investments.

3.2 Smart Infra: Diversification by Risk Factors

Using risk factors for diversification can reduce the potential for significant losses and extreme risks, while also offering better long-term risk adjusted returns. Over the last decade, the use of risk factors in portfolio diversification has increased in the publicly traded markets in general and equities in particular. Bender et al. (2010) found that a portfolio that is based on multi-factor generated similar returns but significantly lower volatility comparison with the traditional 60/40 equity-bond portfolio. Briere and Szafarz (2021) and Bessler et al. (2021) showed that, when short selling is restricted (as is the case with unlisted infrastructure), factor diversification outperforms sector diversification during economic downturns.

In this section, we consider using the logic of factor investing in the context of unlisted infrastructure investments. This strategy involves assessing individual infrastructure investments for their exposure to key risk factors identified in the asset pricing literature, in particular with regard to unlisted infrastructure (Bird et al., 2014; Blanc-Brude and Tran, 2019).

We focus on five factors that statistically explain the risk premium in infrastructure investing and therefore drive the systematic risk component of these assets. That is to say, these key factors are found to explain observed transaction prices and their implied expected returns in the EIPA pricing model. These risk factors can be defined as follows:

- Size: This risk factor can serve as a a proxy of liquidity premium. Larger projects are risky as they are complex to build and operate and require larger sunk costs. As infrastructure investments are highly illiquid, we can expect larger private infrastructure companies to be priced at a discount. As illustrated in Figure 12 and Table 13 in the appendix, size, which is measured as Small minus Large Size companies, has a negative impact on the premium, implying that smaller companies are expected to underperform larger companies. This means that large companies tend to have a higher risk premium than small companies.
- Leverage: The leverage ratio is measured as the ratio of total liabilities to total assets. As the infrastructure sector is reliant on high capital requirements to construct large-scale projects, credit constitutes an important source of finance, such that the leverage ratio can range from 50% to 95% depending on the sector (Bucks, 2003; Beeferman, 2008; Blanc-Brude et al., 2018).
- Investment: Measured by the CAPEX to total assets ratio, infrastructure companies possess a unique investment proposition. They combine the aspects of value and growth stocks but with distinct risk and return characteristics influenced by their long-term, sunk cost nature and sensitivity to business cycles. For instance, they often have negative book equity in their initial "greenfield" stage, which may categorise them as "value" assets, while their long-term commitments and sunk capital expenditure during development signal their growth potential. Therefore, unlisted infrastructure investments tend to be relatively cheaper and thus command higher returns at the greenfield (value) stage. Figure 12 and Table 13 show the effects of each of the risk factors on the companies returns.
- Profitability: Measured by the return on assets (ROA) can have direct and negative impacts on the risk premium of a company. Higher profits lead to a lower risk premium and therefore a higher valuation. [1]
- Term spread: Measured by the difference between long and short-term interest rates at the time and the country of the company of interest. This risk factor is a proxy of country risk.

1 - The risk factor we consider below is the inverse of profitability, chosen to ensure that the assets have high exposure for all the risk factors.

Table 5: Risk factors portfolios across several values for the Multi-Factor Score filter. Each portfolio contains only 25 assets. The Sharpe ratio for each portfolio is the average of 100 simulated portfolios. Calculations are in USD.

Risk Factor	Multi-Factor Intensity ->	90%	75%	50%
Size Risk Factor	Number of Assets Sharpe Ratio [Up, Lo Bound]	25 0.345 [0.183, 0.507]	25 0.262 [0.017, 0.506]	25 0.270 [0.023 , 0.517]
Leverage Risk Factor	Number of Assets Sharpe Ratio [Up, Lo Bound]	25 0.341 [0.163, 0.519]	25 0.319 [0.119 , 0.518]	25 0.361 [0.093 , 0.629]
Investment Risk Factor	Number of Assets Sharpe Ratio [Up, Lo Bound]	25 0.302 [0.162 , 0.442]	25 0.283 [0.079 , 0.486]	25 0.294 [0.025, 0.562]
Profit Risk Factor	Number of Assets Sharpe Ratio [Up, Lo Bound]	25 0.250 [0.107 , 0.394]	25 0.235 [0.014 , 0.456]	25 0.306 [0.041 , 0.570]
Term Spread Risk Factor	Number of Assets Sharpe Ratio [Up, Lo Bound]	25 0.275 [0.130 , 0.420]	25 0.210 [0.018 , 0.401]	25 0.303 [0.052 , 0.553]
All Risk Factors	Number of Assets Sharpe Ratio [Up, Lo Bound]	25 0.357 [0.173, 0.540]	25 0.291 [0.079 , 0.503]	25 0.284 [0.034, 0.533]

These factors are further illustrated in the appendix. Table 13 shows the effects of each of the risk factors on company returns. Table 14 shows the mean factor loadings (betas) for these five risk factors overtime in the infraMetrics universe. Figure 12 shows the returns of factor mimicking portfolios in this universe.

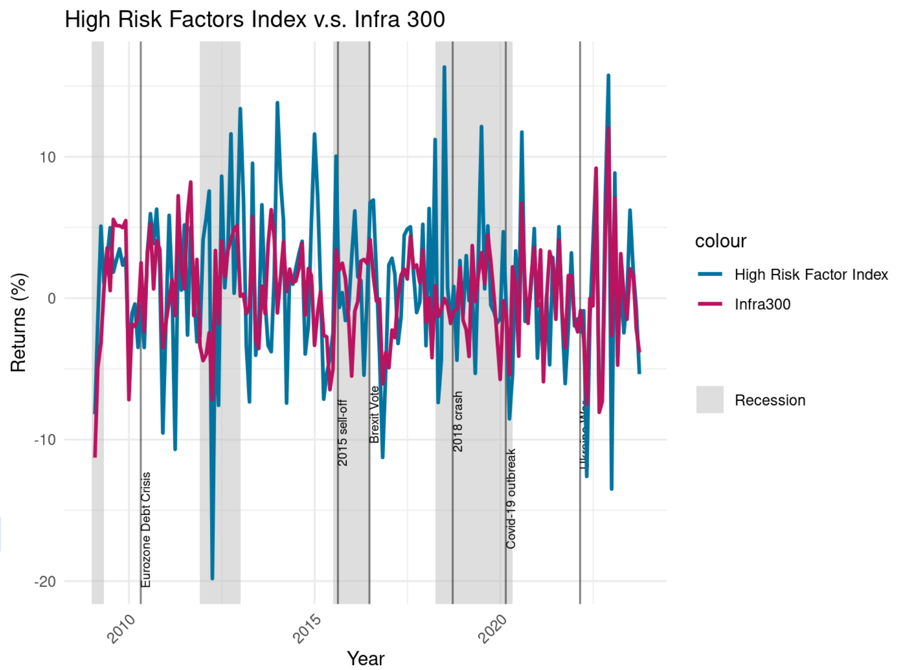
3.2.1 High Factor Intensity Portfolios

Investing based on factor tilts is also known as "Smart Beta" investing. We focus on the approach of Amenc and Aguet (2019) (Smart Beta 2.0) when constructing a diversified portfolio across risk factors. We refer to this approach as "Smart Infra" in the case of private infrastructure investments. The investment selection process for a long only portfolio is based on choosing assets according to their factor characteristics then diversification away specific risks. The approach follows the following steps:

1. We start by selecting the top 50% investments based on their individual factor scores for each of the five factors: size, investment, leverage, profit and term spread. (Note: We first standardise and normalise the scores to have a mean of 0 and a standard deviation of 1.)
2. The selected companies are then narrowed down based on their multi-factor score. The multi-factor score is calculated as the arithmetic average of the five factor scores, keeping the companies with a multi-factor score in the top 10%.
3. A diversified multi-strategy weighting schemes is then applied across four diversification strategies to diversify idiosyncratic risks and achieve the highest possible risk-adjusted return:
   a) Maximum Deconcentration: This weighting scheme provides equal weights for each investment in our filtered universe to minimise the investment related risk.
   b) Diversified Risk Weighted: This weighting scheme provides lower weights to investment with high volatility and higher weights to investments with low volatility.
   c) Maximum Decorrelation: This weighting scheme minimises the volatility of the portfolio based on historical correlation between the individual stocks.
   d) Maximum Sharpe ratio: This weighting scheme maximises the risk-adjusted return, measured by the Sharpe ratio based on the returns and volatilities of individual investments.

The rationale behind this approach is as follows: a portfolio built based on the size exposure, for example, should have a strong exposure to the

Figure 8: High risk factors index. Correlation between the two series is 0.58. The shaded areas represent the OECD recession periods. The vertical black lines represent financial and policy shocks.



size factor and a strong multi-factor intensity overall. (A weak multi-factor intensity could result from exposures to other risk factors such as leverage, profitability, investment or term spread.) This results in the portfolios not only having a strong factor intensity, but also a very good factor de-concentration. This makes the portfolios less sensitive to the underperformance of one specific factor and enable them to benefit from a higher potential for outperformance over the long run (see Amenc et al., 2020, for a detailed discussion).

Table 5 presents an analysis of portfolio construction based on risk factor exposure. We show six portfolios, the first five are constructed based on exposure to a single risk factor, while the sixth combines exposures across various multi-factor scores. Each of these portfolios are invested in 25 assets as previous research shows that infrastructure investors hold up to 25 assets at any one time. By simulating 100 portfolios, each comprising 25 randomly chosen assets selected for their varying degrees of risk factor exposure—from strong to weak—we demonstrate that portfolios with stronger exposure to the specified risk factors exhibit higher Sharpe ratios on average, compared to those with weaker exposure.

For this, we build 100 portfolios, each investing in as little as 25 assets with varying exposures to distinct risk factors, and find a notable improvement in portfolio performance: **holding 25 assets on average across different exposures to risk factors results in higher Sharpe ratio than investing in 100 assets randomly** in the naïve strategies described above.

This finding underscores the effectiveness of a targeted investment approach. Investors can enhance risk-adjusted returns by focusing on assets with significant exposure to specific risk factors, such as Size or Leverage, or a composite exposure to multiple risk factors. This analysis indicates that, even within the constraints of a small asset pool, a deliberate and selective approach, prioritising assets that exhibit robust exposure to a balanced mix of risk factors, can significantly outperform more generalised investment methods.

Table 5 also shows that by adjusting the intensity of exposure to multi-factor scores i.e., creating indices based on the top 10%, 25% and 50% of companies ranked by their comprehensive multi-factor scores, we investors can achieve superior risk-adjusted returns than those attained through undifferentiated, conventional strategies. As the filtering for the multi-factor scores is relaxed, the Sharpe ratio decreases and the upper and lower bounds of the confidence interval widen. In other words, as the process becomes less selective and incorporates assets with a wider range of multi-factor scores, the optimality of the portfolio's risk-adjusted returns diminishes. That is to say, when portfolios include a more diverse array of assets with less strict multi-factor score filtering, they exhibit greater performance variability and potentially higher risk, as reflected by the wider confidence intervals.

As before, we apply mean-variance efficiency in Table 1 to evaluate the diversification benefits of incorporating risk factor exposures in portfolio construction. The test confirms that a portfolio of 25 assets, selected randomly with high exposure to all five risk factors, achieves mean-variance efficiency by exhibiting lower variance compared to the benchmark of 100 assets. This result illustrates the enhanced diversification benefits and efficiency gains of a focused approach on risk factors in infrastructure portfolio construction.

Finally, Tables 3 and 4 illustrate a comparison between the three naïve diversification strategies and the risk factors diversification strategy across the equal or value weighting schemes, respectively. We see that naïve strategies all perform similarly on average with 100 assets, whether sector and country diversifications are explicitly taken into account - this is because, with 100 assets, investors are mechanically exposed to many sectors and countries. The average Sharpe ratio is circa 0.15.

With high factor intensity portfolios of 25 assets, a Sharpe ratio of circa 0.35 is achieved. In other words, in a portfolio with quarter number of assets, a 100% improvement in the risk-adjusted return of infrastructure investments is possible.

This suggests that a focused approach, prioritising assets with strong risk factors exposure, can achieve superior risk-adjusted returns to the typical approach to diversification which is to invest in more assets, countries and sectors. Such outcomes demonstrates the efficacy of portfolio construction based on rigorous risk factor analysis over merely spreading investments across a wide array of assets, sectors, or geographies without considering their underlying risk profiles.

By focusing on risk factor exposures, investors can construct portfolios that are not only theoretically viable but also practically achievable, leveraging advanced financial modelling and risk assessment techniques.

This point is further illustrated by Figure 8, which shows the monthly time series of the high risk factors index over the period 2009-2023 along with the broad market infra300 equally weighted index, which tracks 300 assets in 15 sectors and 20 countries. While both series have similar co-movements over time, the positive and negative shocks are more nuanced for the high risk factors index than for the infra300. This can be attributed to the infra300's strategy of equitable distribution across all 300 assets, in contrast to the high risk factors index's selective allocation focused on assets with a particular risk profile, foregoing equal weighting.

Next, we consider the implications of having access to a well-diversified portfolio of unlisted infrastructure equity investments for strategic asset allocation.

4. Strategic Asset Allocation: infrastructure in the total portfolio

In this section we consider the potential role of unlisted infrastructure risk factors in multi-asset portfolio allocation. We construct a portfolio that includes nine asset classes, including traditional asset classes such as US equity, emerging equity, corporate bonds, government bonds, commodities and alternative investments such as private equity, real estate, hedge funds, commodities and unlisted infrastructure high-risk factors indices. We then add infrastructure to the portfolio and consider the implications using different optimisation approaches: return targeting, risk targeting and equal risk contribution.

4.1 Approach

For this analysis, we follow Amenc et al. (2022) and compute optimal portfolio weights for a range of risk, return and diversification targets for two profiles of investors, "conservative" and "aggressive" investors. The conservative investors follow a 80:20 strategy to allocate 80% of their portfolios to corporate bonds and 20% to US equities. This is an example of a well-funded pension plan with a focus of liability-driven investment to protect the existing fund contribution and hedge their liabilities. The second type is "aggressive" investors who follow a 40:60 strategy and allocate 60% of their portfolio to US equity and 40% to corporate bonds. Such an investor would have a higher risk tolerance and want to achieve higher returns. Table 8 shows the risk and return associated with each profile. The conservative investors have an annualised expected return and volatility of 4.98% and 7.4% respectively, while the aggressive investors have and expected return and volatility of 5.8% and 11.8%. Under both strategies, we assume that the investors select private funds to invest a target of a 20% overall allocation to private funds (such as real estate, private equity, hedge funds and private infrastructure companies) based on their risk factor exposure. We also assume that the investors build their portfolios just once and do not rebalance them, as rebalancing is not possible with private infrastructure investments.

We then compute two types of mean-variance optimisations, a return-targeting and a risk-targeting optimisation, as well as a risk-only optimisation technique.

- Return targeting: This strategy is based on finding an allocation that achieves a portfolio return greater than or equal to a fixed target, whilst minimising the portfolio risk. The return target is greater than or equal to the 60:40 and 80:20 portfolios. The portfolio is fully invested, and short selling is not allowed. We consider the role of the strategic asset allocation of our risk factors indices across various assets classes such as US equities, emerging markets equities, corporate bonds, government bonds, real estate, private equity, hedge funds, and commodities.
- Risk targeting: This strategy is based on finding the optimal portfolio weights that keep the portfolio risk below the target while maximising returns.
- Equal risk contribution (ERC): This strategy is based on finding the optimal portfolio weights to minimise the risk contribution from all asset classes, while minimising the Effective Number of Constituents or ENC. Iliquid assets have a maximum weight of 20%.

For the first two strategies, we also apply the following two constraints:

Table 6: Average industry expectations of risk and return across different asset classes. The forward-looking data for asset classes with exception to the high risk factors are the average of the forward-looking data provided by Blackrock, JP Morgan, Morgan Stanley, BNY Mellon, Invesco, Schroders, Northern Trust, State Street, Callan and Envestnet. For the high risk factor index, we use the weighted average expected returns estimated by EIPA and the historical volatility based on the Smart Infra Beta diversified weights. Naive Index is an index built with 10 infrastructure assets chosen randomly. Infra300 expected returns are the forward looking IRR and volatility is the 10 years annualised returns. The Sharpe ratios are calculated with an assumption of risk free rate of 0%. Results are in USD.

Asset Class	Return	Risk	Sharpe Ratio
High risk factors index	10.03%	19.19%	0.588
Infra300	10.5%	10.97%	0.683
Naive Index	8.8%	17.49%	0.502
US equity	6.57%	16.12%	0.408
Emerging equity	8.35%	20.21%	0.413
Corp bonds	4.58%	5.16%	0.888
Gov bonds	4.03%	4.63%	0.871
Real estate	6.54%	12.20%	0.536
Private equity	8.92%	20.83%	0.428
Hedge funds	5.37%	7.04%	0.762
Commodity	4.06%	17.32%	0.235

Table 7: Infra correlations are based on long-term in-sample data from 2009-2019. Correlations between infra and private equity are assumed to be the same as with equity. Other asset classes expectations are based on the estimates of investment managers and consultants: Blackrock, JP Morgan, Morgan Stanley, BNY Mellon, Invesco, Schroders, Northern Trust, State Street, Callan and Envestnet.

	Equity	Emerging Equity	Corp Bonds	Gov Bonds	Real Estate	Private Equity	Hedge Funds	Comm-odity	High Risk Factors
Equity	1	0.71	0.27	-0.16	0.43	0.78	0.72	0.3	-0.14
Emerging Equity	0.71	1	0.32	-0.15	0.36	0.65	0.67	0.39	-0.1
Corp Bonds	0.27	0.32	1	0.65	0.08	0.17	0.44	0.13	0.03
Gov Bonds	-0.16	-0.15	0.65	1	-0.23	-0.41	0.02	-0.14	0.34
Real Estate	0.43	0.36	0.08	-0.23	1	0.45	0.35	0.19	0.16
Private Equity	0.78	0.65	0.17	-0.41	0.45	1	0.65	0.31	-0.14
Hedge Funds	0.72	0.67	0.44	0.02	0.35	0.65	1	0.35	-0.14
Commodity	0.3	0.39	0.13	-0.14	0.19	0.31	0.35	1	-0.28
High Risk Factors	-0.05	-0.08	0.07	0.22	0.15	-0.05	-0.08	-0.21	1

Table 8: Investor profiles used to compare optimal allocations.

	Conservative investor	Aggressive investor
Allocation	Equity: 20% Corp Bonds: 80%	Equity: 60% Corp Bonds: 40%
Target return	4.98%	5.8%
Target risk	7.4%	11.8%

- ENC is at least six.
- The allocation to all illiquid assets (real estate, private equity, hedge funds, commodities, risk factors indices) does not exceed 20% of the portfolio, leaving at least 80% invested in liquid assets. The choice of 20% is ad hoc but consistent with average allocations for some large institutional investors such as US public pension funds.

4.2 Inputs

For asset classes other than the high risk factors index and infra300, we rely on industry estimates of expected returns, return volatility and correlations, as provided by a broad spectrum of financial institutions. These are formed as a combination of long-term historical observations and forward-looking views based on short-term variations in risk and return of each asset class. We consider data provided by leading consultants and asset managers: BlackRock, JP Morgan, Morgan Stanley, BNY Mellon, Invesco, Schroders, Northern Trust, State Street, Callan and Envestnet. We use data reported at the end of 2023, taking the average of these views as our forward-looking estimate. The data provided by each organisation is available in the Appendix, in Tables 15 and 16 and their average estimates are presented in Table 6.

For infrastructure, we build an index based on the Smart Infra approach described in the previous chapter. Our smart Infra methodology resulted in having an index consists of 35 assets and is tilted towards factors that offer higher returns such as size, leverage, profitability, investment and the term spread. As before, the diversified multi-

Table 9: Sharpe ratio comparison across portfolios with and without Infra high risk factors index. Sharpe ratio is calculated on the basis of 1% risk free rate. All calculations are in USD.

	Return Targeting		Risk Targeting	
	80/20	60/40	80/20	60/40
Portfolio w/ High Risk Factors	0.706	0.717	0.690	0.537
Portfolio w/o Infra	0.668	0.631	0.640	0.483

strategy weighting scheme targets the diversification of idiosyncratic unrewarded risks which helps to efficiently capture risk factors rewards. As a result, the asset selection and weighting schemes pick and weight assets across different TICCS sectors and geographies, reducing sector specific and macroeconomic risks. The high factor intensity (HFI) index created includes companies from nine countries and all the TICCS Industrial superclass sectors. The expected returns of the HFI index are obtained from infraMetrics. (see Amenc et al., 2022, for a description of the methodology).

4.3 Results

4.3.1 Return targeting

The results of the optimisation problem showing the detailed weights and the portfolio performance for each type of investor, across different filtering for the risk factor indices for the risk targeting technique, are displayed in Table 10 and figure 9.

The two investor profiles are found to have a positive allocation to infrastructure, ranging from 4.4% to 9.2%. For each profile, the risk factor indices have greater weights than other private asset classes such as real estate, private equity, and hedge funds. This can be explained by the performance of this index in Tables 6 and 7 since infrastructure generates the highest return, and risk-adjusted return, as well as the lowest correlation with other asset classes.

4.3.2 Risk targeting

The results of the risk targeting optimisation are displayed in Table 11 and Figure 10. We implement this exercise using a range of volatility targets, ranging from 6.5% to 12%, which span all possible portfolio volatilities under the predefined constraints. A conservative investor's portfolio has a portfolio volatility of 7.4%, while an aggressive investor has a portfolio volatility of 11.8%.

As the risk appetite of the investors becomes more aggressive, the proportion of their holdings in fixed income and infrastructure shrinks as they switch into riskier asset classes such as equities, real estate and private assets. For instance, in a 80:20 portfolio, there is no private equity. However, the infrastructure indices are always present regardless of whether investor are conservative or aggressive. Infrastructure weights increase as investors become more conservative as these assets can act as a source of ALM hedging. Holdings of the HFI infrastructure Index are always positive and high, and range from 13.1% for a conservative investor to 12% for a more aggressive investor.

4.3.3 Equal Risk Contribution (ERC)

In this case, we do not refer to investor profiles as there is no return or risk target. The results of this optimisation problem are displayed in Table 12 and Figure 11 show the results for varying ENC targets for three specific cases: low (5), medium (6) and high (7) ENC target.

With the low ENC target of 5, fixed income has the highest allocation in the portfolio of 57.9%, in line with the focus of this approach to minimise the risk contributions. As the ENC target increases, the weights of other asset classes must increase in order to satisfy the ENC constraint, making the individual risk contribution less equal. Thus, the volatility of the portfolio increases from 5.4% for the low ENC target to 7.6% for the highest ENC target. The allocation to infrastructure asset class decrease when moving from

Figure 9: Optimal allocation with return-targeting approach under different return target constraints. Infrastructure is the high risk factors index constructed using the Smart Infra approach.

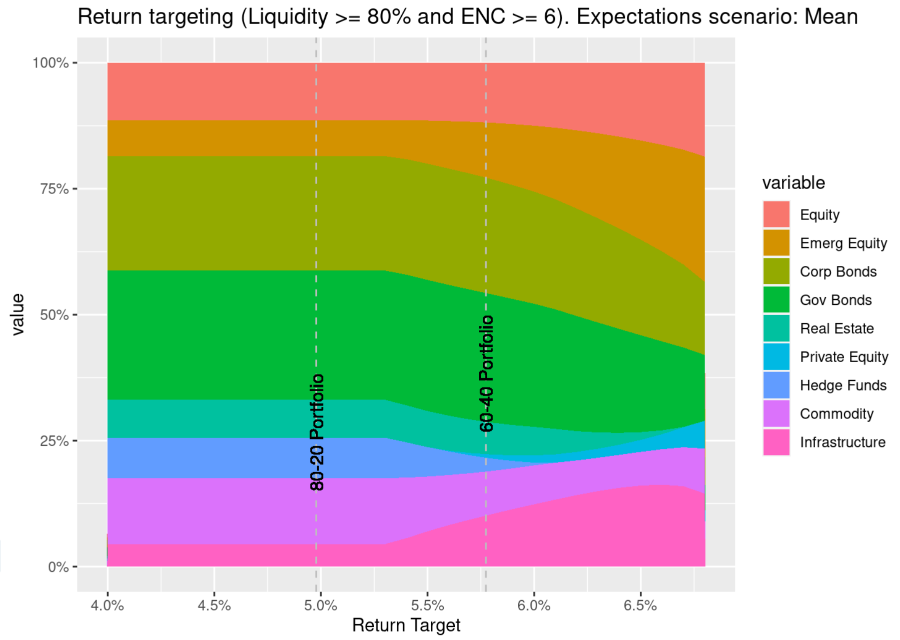


Figure 10: Optimal allocation with risk-targeting approach under different risk target constraints. Infrastructure is the high risk factors index constructed using the Smart Infra approach.

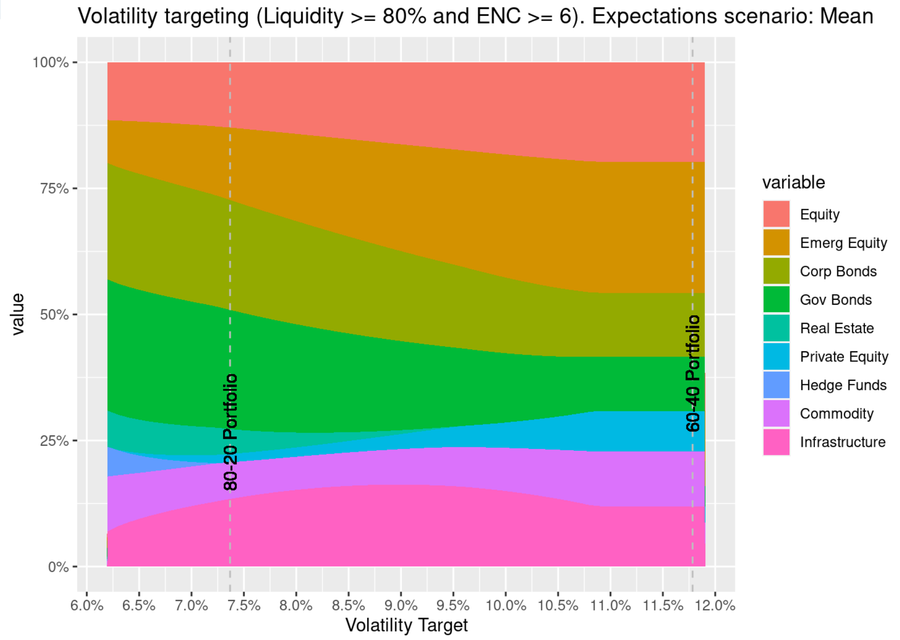


Table 10: Optimal allocation with return-targeting approach under different risk targets. For top 10% HFI, the High Risk Factors Index includes 35 assets across different sectors and geographic locations. Sharpe ratio is calculated on the basis of 1% risk free rate. All calculations are in USD.

	Asset Class	Conservative	Aggressive
Return Target		4.98%	5.8%
Weights	US equity	11.4%	11.8%
	Emerging equity	7.17%	11.29%
	Corp bonds	22.69%	22.90%
	Gov bonds	25.62%	25.5%
	Real estate	7.61%	6.44%
	Private equity	0%	0.95%
	Hedge funds	8.10%	2.43%
	Commodity	13.1%	8.4%
	Smart Infra	4.4%	9.2%
Return		5.31%	5.8%
Risk		6.11%	5.9%
Sharpe Ratio		0.706	0.717

Table 11: Optimal allocation with risk-targeting approach under different risk targets. For top 10% HFI, the High Risk Factors Index includes 35 assets across different sectors and geographic locations. Naive Index is created with 10 infrastructure assets chosen at random. Sharpe ratio is calculated on the basis of 1% risk free rate. All calculations are in USD.

	Asset Class	Conservative	Aggressive
Volatility Target		7.4%	11.8%
Weights	US equity	12.9%	19.7%
	Emerging equity	14.4%	26.0%
	Corp bonds	21.9%	12.7%
	Gov bonds	23.7%	10.7%
	Real estate	5.1%	0%
	Private equity	1.8 %	8%
	Hedge funds	0 %	0 %
	Commodity	7.1%	10.9%
	Smart Infra	13.1%	12%
Return		6.1%	6.8%
Risk		7.4%	10.9%
Sharpe Ratio		0.690	0.537

Table 12: Optimal allocation using equal risk contribution approach under different ENC targets with the top 10% HFI high risk factors index. Sharpe ratio is calculated on the basis of 1% risk free rate. All calculations are in USD.

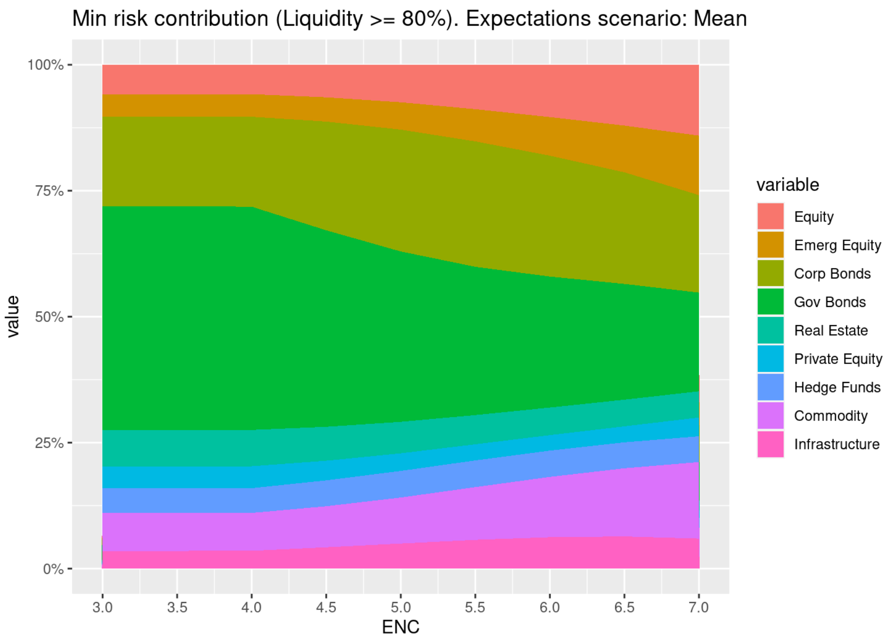
	Asset Class	High ENC Target	Mid ENC Target	Low ENC Target
ENC Target		7	6	5
Weights	US equity	14.1%	10.4%	7.4%
	Emerging equity	11.8%	7.7%	5.4%
	Corp bonds	19.3%	24%	24.1%
	Gov bonds	19.6%	26%	33.8%
	Real estate	5.2%	5.5%	6.3%
	Private equity	3.7%	3.1%	3.5%
	Hedge funds	5.1%	5.3%	5.3%
	Commodity	15.2%	15.2%	10.5%
	Smart Infra	5.9%	6.2%	4.9%
Return		5.7%	5.5%	5.3%
Risk		7.6%	6.3%	5.4%
Sharpe Ratio		0.621	0.714	0.793

a low to high ENC target and allocation to infrastructure ranges from 6% to 5%. Similarly, the lowest risk and highest Sharpe ratio are achieved with the low ENC target.

Table 9 presents a comparison of Sharpe ratios across different portfolio strategies with and without infrastructure. In all scenarios, the portfolios that incorporate infrastructure assets consistently achieve higher Sharpe ratios. This confirms the positive role that infrastructure can play in the portfolio. The results above illustrate, across three different portfolio optimisation techniques, that private infrastructure can indeed play an important role in a multi-asset portfolio as a strategic asset class that complements other allocation classes. Allocations are found to range from 4.5% to 13% depending on the investor objectives and profile.

For this exercise we also used other proxies of the infrastructure asset class, including the infra300 index, which is a broad market index but not tilted to specific factors. Instead the infra300

Figure 11: Optimal allocation using equal risk contribution approach under different ENC targets. Infrastructure is the high risk factors index constructed using the Smart Infra approach.



captures the weight of the different TICCS classes in the universe. Results were equally positive in terms of the potential role of infrastructure in a total portfolio. However the infra300 is less risk-efficient than the HFI index and only the results for the HFI index were reproduced in this paper.

5. Conclusions

This paper makes several important points on incorporating unlisted infrastructure equity into portfolio construction and asset allocation.

When it comes to **portfolio construction**, and building a well-diversified infrastructure portfolio, we have shown that the standard ("naïve") approach of adding more assets, sectors and geographies is a very inefficient and expensive way to diversify such a portfolio. This approaches requires investing in hundreds of assets, a solution that is not accessible to most investors, short of investing via funds of funds, which can also expensive in terms of fees. In other words, diversifying an infrastructure portfolio can seem hard, maybe even impossible, if investors remain wedded to the "more is less" (more assets is less risk) concept of diversification.

We also showed that using the intrinsic risk characteristics of infrastructure investments to build portfolios with high risk-factor exposures can achieve twice the diversification of the naïve approaches with 10 times fewer assets. A "smart" high-factor intensity infrastructure portfolio takes advantage of the fact that risk factors are remunerated (earn a premium in the market) but are also independent (orthogonal) and thus diversify portfolio returns faster. In this case, "less is more" (fewer assets can achieve higher diversification).

This is an important finding as it shows that investors can build well-diversified and investible products that provide a genuine "strategic" access to the asset class – rather than just making very active bets on a few assets. While asset selection and timing are of course a source of manager alpha, being exposed randomly to a few assets leaves out the desirable "betas" that make infrastructure genuinely attractive as an asset class.

Turning to **strategic allocation**, we have shown that whatever the investor profile and portfolio optimisation objective, unlisted infrastructure equity can play a key role in the total portfolio. This is especially the case if it can be invested in "as an asset class" i.e., on a well-diversified basis and therefore using the *Smart Infra* approach described in this paper.

The differences in return volatility and correlation between the infrastructure asset class, as measured using infraMetrics data and therefore capturing the genuine volatility of the asset class, suggest that in a portfolio of 10 asset classes including traditional and alternative investments, unlisted infrastructure should occupy a bucket typically ranging between 4.5% and 13% of the portfolio.

To conclude, it is important to highlight the feasibility of the Smart Infra approach described in this paper. Hundreds of bets can be necessary to build a portfolio with fully diversified idiosyncratic risks unless these assets are selected on the basis of their risk-factor exposures. Trying to add decorrelation to the portfolio by adding more assets in different sectors and countries ignores the fact that investments are not only linked by sectors and countries but also by their risk profile as a business i.e., the risk factors described in this paper. By definition, these risk factors are universally available in all assets because they represent the systematic risk that the market prices in these assets. This universal availability enables investors to access exposure to these factors much more easily than sector and country bets.

Defining a diversification strategy thus "We need to add 20 new transport investments in 10 different countries to the portfolio" is a non-starter for any deal team. Instead, "We need to add 10% of exposure to the size factor to the portfolio" is relatively easily implemented.

This research highlights an implementable approach to building better diversified portfolios of infrastructure at a low cost and in a replicable manner across multiple funds or products. This is important because it gives investors genuine access to the asset class betas. It's also essential for any retail or wealth management product that is essentially a long-term investment product – and not an active bet on a few infrastructure investments, however well-timed, selected or managed.

6. Appendix

Figure 12: Unlisted Infrastructure equity risk factor returns. Source: InfraMetrics. Size factor is measured as the small minus Large size. Leverage is measured as high minus low leverage. Investment is measured as high minus low investment. Profit is measured as high minus low profit.

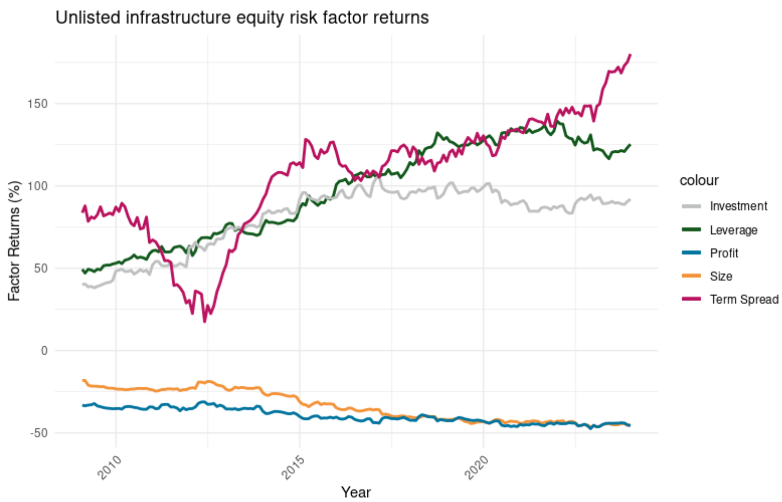


Table 13: Unlisted infrastructure equity risk factor returns. Source: InfraMetrics. Market Factor Return is the average return across all companies.

	Market (%)	Size (%)	Leverage (%)	Investment (%)	Profit (%)
12m	2.78	-2.82	-2.93	0.23	0.68
5Y	1.42	-2.14	0.60	-0.28	0.20
10Y	6.54	-3.55	1.97	0.93	-0.52
15Y	8.32	-2.97	2.41	2.05	-0.52
22Y	9.18	-2.71	3.16	2.82	-1.85

Table 14: Risk factors exposure for Global Infrastructure. Source: InfraMetrics.

	Leverage	Size	Term Spread	Profitability	Investment
Latest quarter	73.89%	1692.79 USD (mn)	0.45%	13.29%	4.08%
One year ago	73.39%	1624.45 USD (mn)	1.37%	13.37%	3.99%
Three years ago	74.44%	1538.97 USD (mn)	1.25%	10.95%	4.17%
Five years ago	76.68%	1438.69 USD (mn)	1.62%	11.67%	5.25%
Ten years ago	77.47%	1218.72 USD (mn)	3.25%	11.25%	6.92%

Table 15: Expected returns estimates from leading asset managers and consultants

	Black Rock	JP Morgan	BNY Mellon	Northern Trust	Morgan Stanley	Invesco	Schroders	State Street	Callan	Envestnet PMC
US Equity	5.90%	7.00%	7.40%	6.30%	5.20%	7.00%	6.90%	5.90%	7.25%	6.85%
Emerging Equity	10.20%	8.80%	7.30%	5.90%	7.80%	9.60%	10.60%	7.20%	7.45%	8.69%
Corp Bonds	4.20%	5.10%	4.80%	4.70%	NA	5.30%	4.80%	3.50%	4.25%	NA
Gov Bonds	3.80%	3.90%	3.90%	NA	NA	4.70%	3.90%	4.00%	NA	NA
Real Estate	NA	8.20%	6.60%	NA	5.00%	NA	NA	NA	NA	6.34%
Private Equity	10.00%	9.70%	8.80%	9.60%	8.10%	NA	8.00%	7.60%	8.50%	9.99%
Hedge Funds	6.70%	5.00%	5.50%	4.50%	NA	4.40%	5.70%	5.60%	5.55%	NA
Commodity	NA	3.80%	2.20%	NA	5.00%	5.60%	3.90%	3.60%	3.50%	4.90%

Table 16: Expected risk estimates from leading asset managers and consultants

	Black Rock	JP Morgan	BNY Mellon	Northern Trust	Morgan Stanley	Invesco	Schroders	State Street	Callan	Envestnet PMC
US Equity	17.30%	16.19%	17.90%	15.30%	13.40%	16.80%	15.40%	15.50%	17.75%	15.61%
Emerging Equity	20.90%	21.20%	20.30%	20.80%	19.30%	24.80%	17.20%	10.10%	25.70%	21.75%
Corp Bonds	5.20%	4.28%	4.70%	4.80%	NA	6.10%	7.30%	4.80%	4.10%	NA
Gov Bonds	5.10%	3.27%	3.30%	NA	NA	4.60%	6.30%	5.20%	NA	NA
Real Estate	NA	16.05%	8.70%	NA	16.70%	NA	NA	NA	NA	7.34%
Private Equity	32.20%	20.06%	23.50%	19.70%	16.20%	NA	22.50%	11.20%	27.60%	14.49%
Hedge Funds	6.10%	5.80%	6.70%	6.20%	NA	8.60%	9%	5.50%	8.45%	NA
Commodity	NA	18.00%	16%	NA	15.30%	23.80%	14.30%	17.10%	18%	16.02%

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