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Achieving Diversification in Unlisted Infrastructure Investment: A Smart Infra Portfolio Construction

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KEY FINDINGS

- Building an unlisted infrastructure equity portfolio by adding more assets, sectors, and geographies is a very inefficient way to increase diversification.
- Utilizing the intrinsic risk characteristics of infrastructure investments, rather than increasing the number of assets, can create highly diversified portfolios with fewer assets, demonstrating that "less is more" in achieving efficient diversification.
- Once invested in a well-diversified manner, unlisted infrastructure equity can play a significant role in portfolio optimization, enhancing the allocation strategy across traditional and alternative investments.

ABSTRACT

This article explores diversification within the infrastructure investment asset class. The focus is on constructing well-diversified portfolios of unlisted infrastructure equity and the strategic asset allocation benefits of including infrastructure in a multi-asset class portfolio. The authors show that, despite common perceptions, simply increasing the number of assets, sectors, and geographies does not efficiently enhance diversification. Instead, achieving a well-diversified portfolio of infrastructure investments 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. In a multi-asset class portfolio, they demonstrate that, whatever the investor profile and portfolio optimization objective, unlisted infrastructure equity can play a key role in the total portfolio, especially if it can be invested as an asset class, on a well-diversified basis, for example using the *Smart Infra* approach described in this article.

Long-term investors in infrastructure often present diversification as a key characteristic of their strategy. A recent survey of institutional investors by Andonov, Kraussl, and Rauh (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 study, using the infra300 index as a proxy of the asset class, we showed that returns between infrastructure and capital markets are imperfectly correlated and 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.

Although 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 article, 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 5 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, but 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 minimize the total portfolio risk for a given level of return, or maximize 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 past 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, among 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 a monthly basis, how much infrastructure should investors hold in their portfolio alongside stock, bonds, and other private assets and alternatives?

The rest of this article is structured as follows: In the next section, 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.

In the third section, we test four different ways to diversify a portfolio of infrastructure equity investments. The first three consist of adding more assets, adding more sectors (and assets), and adding more countries (and assets) to a portfolio. We label these three diversification strategies as "Brute-Force" because they consist solely in the addition of assets to a portfolio without taking return covariance into consideration explicitly. Instead they assume 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 except for a handful of funds of funds.

In the fourth section, 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.

In the fifth section, 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, depending on the investor's risk profile.

Last, in the final section we conclude and offer recommendation on the practical use of smart infra methodology in unlisted infrastructure investing.

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 another. Hence, with numerous assets, the average value of asset specific risks should become small and could trend toward 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 among investments. In other words, risks that infrastructure investments have in common cannot be diversified away by investing in more assets, because these risks are present in all assets. They can however be invested more or less optimally.

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

First, 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. Because 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 in the following.

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 fund managers often present diversification. We label them "Brute-Force" diversification strategies because they rest on the simple assumption that "more is less," i.e., more assets, sectors, countries are less risk. The main characteristic of these approaches is their high cost: we show that achieving meaningful diversification through this approach is almost impossible short of investing in hundreds of assets, probably through a fund of funds.

Next, we 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 Brute-Force 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 Brute-Force 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®.[1] This sample is designed to be representative of a global universe of 9,100+ unlisted infrastructure companies both in terms of geography and TICCS® (The Infrastructure Company Classification Standards) segments, i.e., business model, activity, and corporate structure. We use price (capital) returns in USD.

BRUTE-FORCE DIVERSIFICATION STRATEGIES

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 5 assets, 10 assets, 15 assets,

[1] https://indices.edhecinfra.com/launcher.

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 optimization 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) among 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 $(R_t) = \mu$, $Cov(R_t) = \Sigma$ 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 optimization problem. The following Lagrangian is solved:

$$\lambda = \mathcal{L} = w'\Sigma w - v + \delta_1(w'\bar{1} - 1) + \delta_2(w'\mu - \beta) - \delta_3 w,$$

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:[2]

- Portfolio weights constraints (δ_1): Enforces the constraint that all portfolio weights sum to one ($w'\bar{1} = 1$), i.e., the capital is fully invested in the portfolio.
- Return matching constraints (δ_2): 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 (δ_3): Enforces the non-negativity of weights. 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 are standard normally distributed for large values of T.

As the sign of the test statistic is identical to the sign of the measure of efficiency, λ, we do not report λ and instead report the value of the test statistic in Exhibit 3.

[2] These constraints reflect the nature of investing in unlisted infrastructure investments, where fund managers invest their capital fully. Additionally, the prohibition on short selling reflects the regulatory and practical limitations commonly associated with private infrastructure investments.

Diversification by Number of Assets

In this first case, we build 100 equally weighted random portfolios for each target number of constituents, from 5 to 100, irrespective of any other sector or geography criteria. This first strategy serves 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.

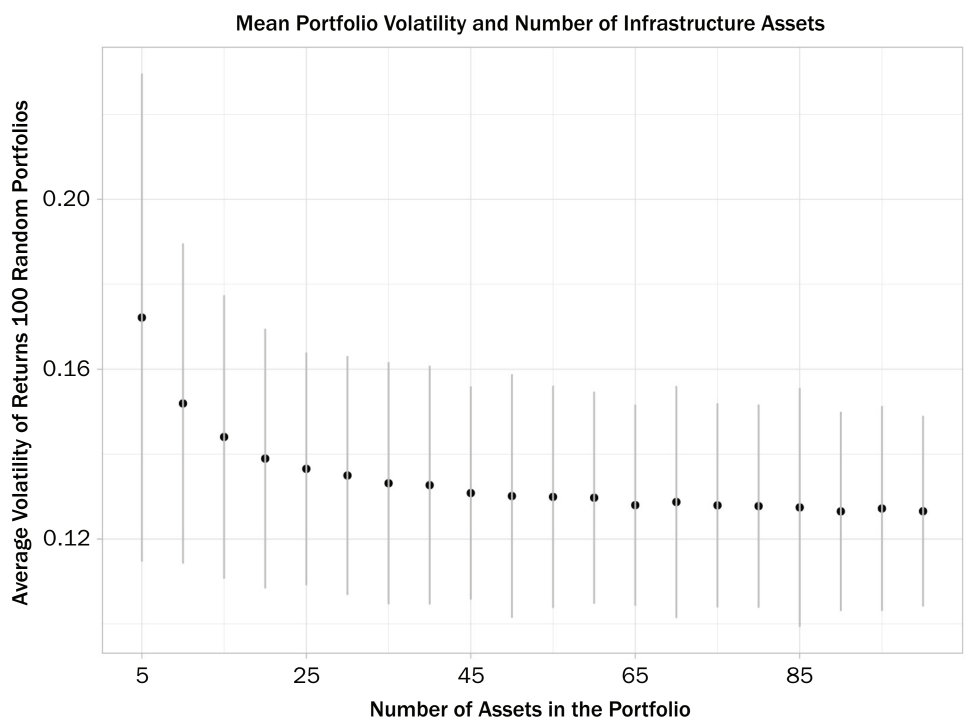
Exhibit 1 shows the mean portfolio capital return variance and its range for 100 portfolios for each group of target number of constituents. It shows that fully reducing portfolio variance risk would, on average, require investing a very large number of assets. The typical 15- to 25-assets portfolio found in infrastructure funds, as long as it is invested randomly, is thus far from being "well-diversified."

Moreover, although 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. Although 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 among asset returns, which means that the price movements of these assets are not perfectly synchronized. 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.

Exhibit 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

EXHIBIT 1

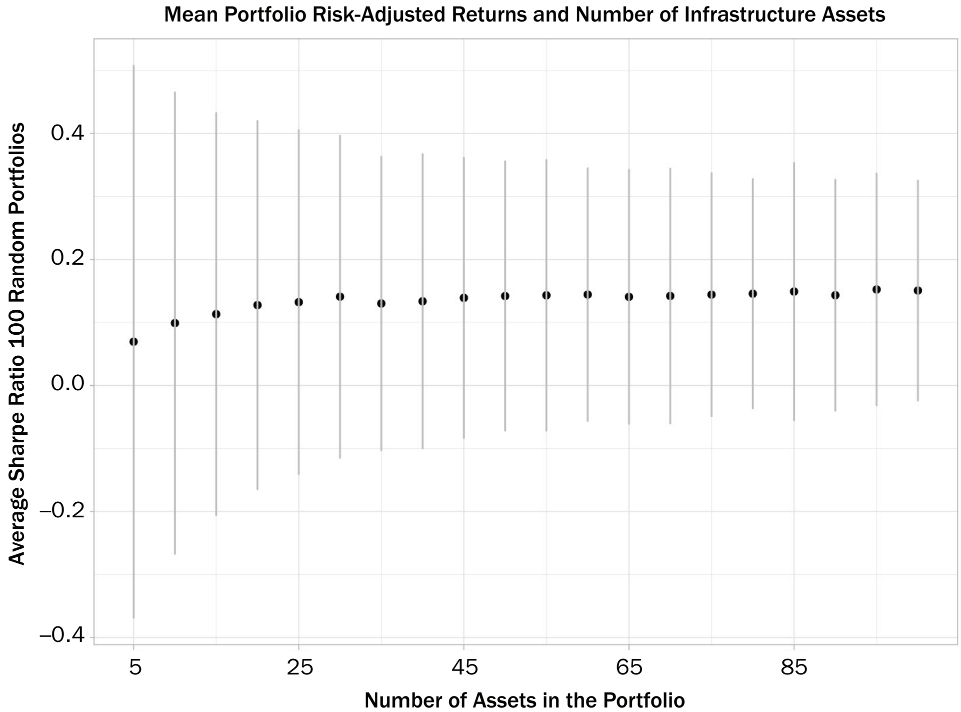
Average Volatility of 100 Random Portfolios for the Brute-Force Diversification by Number of Assets



NOTES: The error bars represent the 95% confidence interval for the risk in the portfolio simulations. Calculations are in USD.

EXHIBIT 2

Average Sharpe Ratio of 100 Random Portfolios for the Brute-Force Diversification by Number of Assets



NOTES: The error bars represent the 95% confidence interval for the Sharpe ratios in the portfolio simulations. Calculations are in USD.

EXHIBIT 3

Mean-Variance Efficiency Test. λ Is the Lagrangian Problem, the Test Statistic is under the Null Hypothesis that $\lambda = 0$

	25 Assets Brute-Force Strategy	25 Assets & 12 Sectors	25 Assets & 12 Countries	Risk Factors Portfolio & 25 Assets
Test statistic (ξ)	2.21	0.13	10.09	–4.65

NOTE: The benchmark is the average of 100 portfolios invested in 100 random assets.

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

Exhibit 3, 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 remains very variable and requires investing in hundreds of assets to be effective.

EXHIBIT 4

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

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 to diversify a portfolio. Because 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 2 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 among individual TICCS® industrial classes in Exhibit 4, 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 2 or 12 sectors. Exhibit 5 shows that a greater number of sectors can lead to higher risk-adjusted returns for any given number of assets.

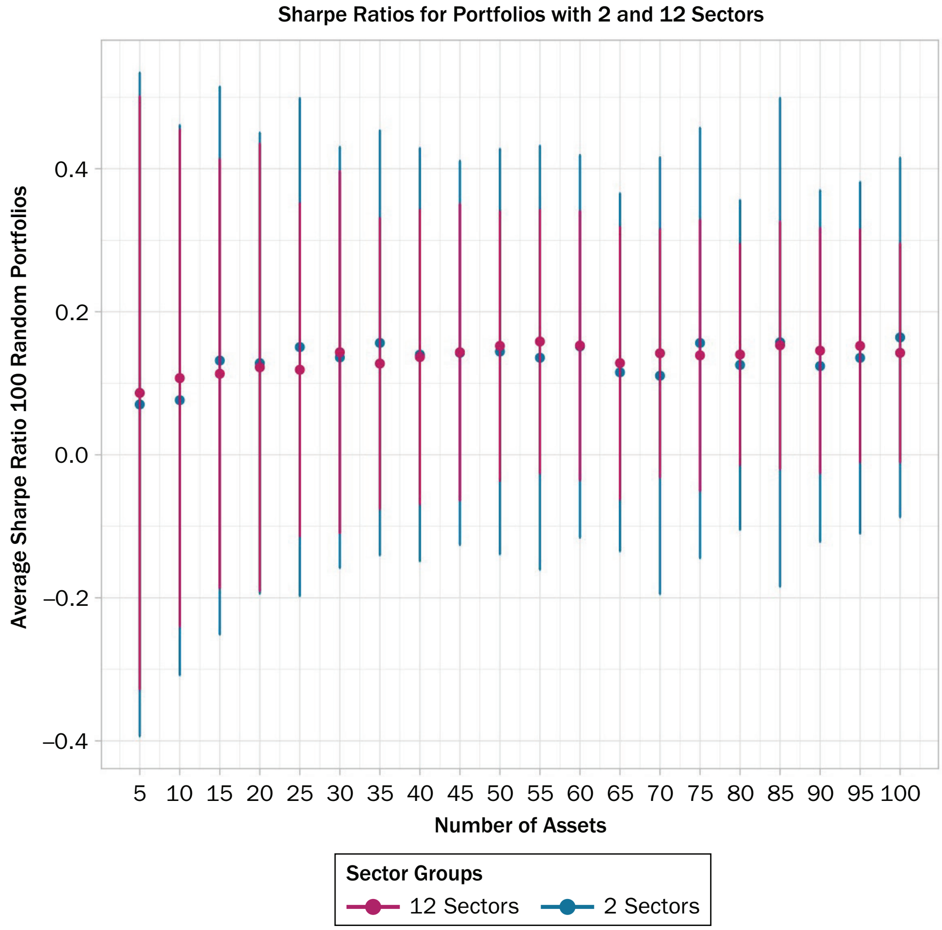
In other words, on average, broadening sector exposure can enhance risk-adjusted returns across various portfolio sizes. Yet, this strategy encounters unique challenges in the context of private infrastructure investment, practical limitations persist, and a given portfolio may be far from the average. 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 2 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.

Exhibit 3, 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.

Likewise, Exhibit 6 shows that diversifying across a range of countries, from 2 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, Exhibit 3, third column shows that a portfolio of 25 randomly chosen assets across 12 different countries is not mean-variance efficient compared

EXHIBIT 5

Brute-Force Diversification by Sector, Risk-Adjusted Return



NOTES: The red and blue bars represent the 95% confidence interval for the Sharpe ratios in the simulations for the 2 and 12 sectors portfolios respectively. Calculations are in USD.

to the benchmark. In addition to this, managing investments across various countries introduces additional regulatory and forex complexity.[3]

Is Diversification Even Possible?

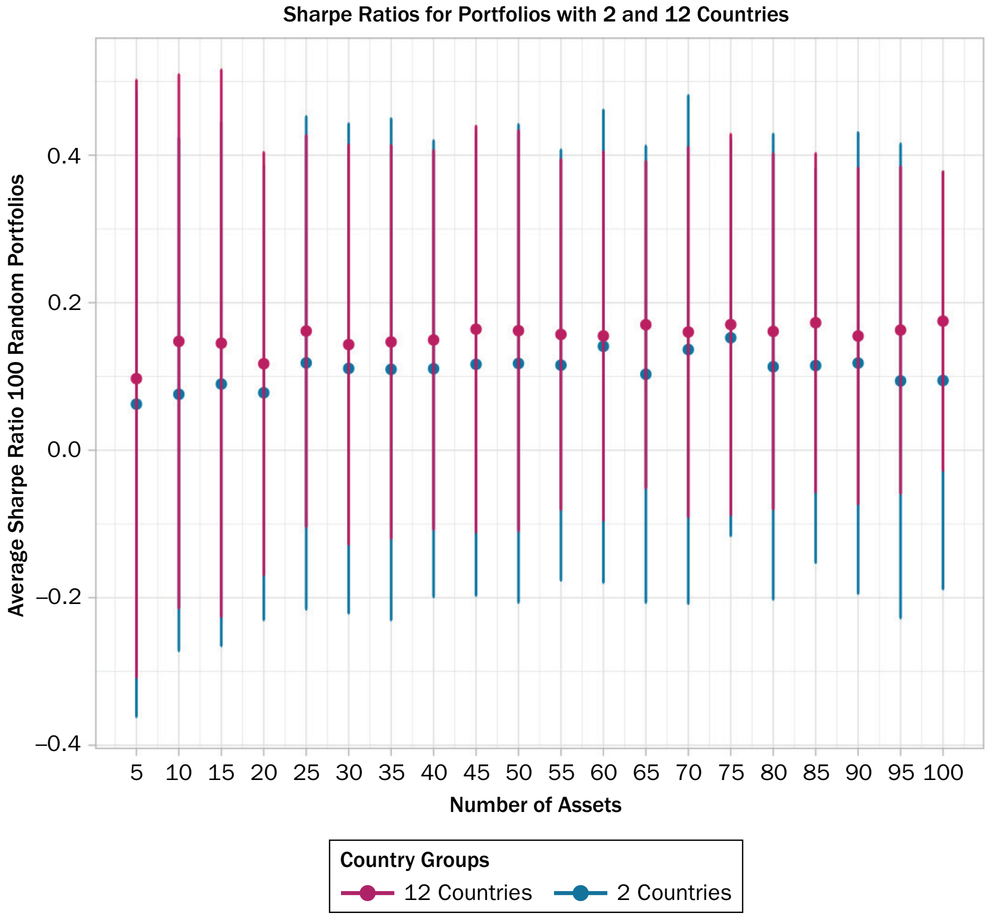
In summary, a fund manager investing in an infrastructure portfolio with a typical number of assets (25) is not likely to be diversified. The Sharpe ratio can vary greatly when the number of assets is low, as shown by the wider confidence interval. As more assets are added, the confidence interval narrows, 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 (Markowitz 1976).

[3] Exhibits A2 through A4 in the appendix present the Sharpe ratios for each strategy using market value weights instead of equal weights. Across all the scenarios, the improvements in the Sharpe ratios are very minimal, and the 95% confidence intervals are broader, compared to those presented in the above portfolios.

EXHIBIT 6

Brute-Force Diversification by Country, Risk-Adjusted Return



NOTES: The red and blue bars represent the 95% confidence interval for the Sharpe ratios in the simulations for the 2 and 12 countries portfolios respectively. Calculations are in USD.

EXHIBIT 7

Comparison between the Three Brute-Force Diversification Strategies with 100 Assets from 100 Simulated Portfolios and Risk Factors Diversification Based on 100 Simulated Portfolios of 25 Assets

	100 Assets Brute-Force Strategy	100 Assets & 12 Sectors	100 Assets & 12 Countries	High Risk Factors Portfolio with 25 Assets
Annualized return	2.91%	2.78%	2.9%	7.6%
Annualized risk	12.7%	12.5%	12.8%	18.5%
Sharpe ratio	0.151	0.143	0.149	0.357
[Up, Lo bound]	[–0.023, 0.325]	[–0.01, 0.296]	[–0.07, 0.368]	[0.173, 0.540]

NOTE: Results are in USD.

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 United States, 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 turn, 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 (that 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.

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 past 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 in comparison with the traditional 60/40 equity-bond portfolio. Briere and Szafarz (2021) and Bessler, Taushanov, and Wolff (2021) showed that, when short selling is restricted (as is the case with unlisted infrastructure), factor diversification outperforms sector diversification during economic downturns. In equity markets, Feng, Giglio, and Xiu (2020) identified 99 risk factors that have been used to explain expected stock returns. Similarly, Amenc and Goltz (2016) emphasized the importance of using statistical tests to evaluate the relevance of these risk factors. This points to a significant issue in equity market analysis: the presence of redundant risk factors that could not present power in predicting the cross section of stock returns. Such redundancy underlines the need for rigorous statistical and econometrics validation to determine which factors are truly predictive of returns and which are not.

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, regarding unlisted infrastructure (Bird, Liem, and Thorp 2014; Blanc-Brude and Tran 2019), where the statistical significance of the risk factors used in our article is documented.[4]

[4] See Blanc-Brude and Tran (2019) for evidence regarding the statistical significance of risk factors in unlisted infrastructure investments.

We focus on five factors that statistically explain and provide an economic rationale to the risk premium in infrastructure investing and, therefore, drive the systematic risk component of these assets. 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 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 Exhibits A6 and A7 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, Hasan, and Whittaker 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 categorize them as "value" assets; 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. Exhibits A4 and A5 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.[5]
- 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.

These factors are further illustrated in the appendix. Exhibit A6 shows the effects of each of the risk factors on company returns. Exhibit A7 shows the mean factor loadings (betas) for these five risk factors over time in the infraMetrics universe. Exhibit A5 shows the returns of factor mimicking portfolios in this universe.

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. This approach is referred to as being "smart" as it not only tilts toward a given factor or group of factors, but also achieves diversification within the factors tilt through the combination of alternative weighting schemes. The investment selection process for a long-only portfolio is

[5] The risk factor we consider in the following is the inverse of profitability, chosen to ensure that the assets have high exposure for all the risk factors.

based on choosing assets according to their factor characteristics, then diversifying 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 standardize and normalize 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 minimize the investment related risk.
   - **(b)** Diversified risk weighted: This weighting scheme provides lower weights to investments with high volatility and higher weights to investments with low volatility.
   - **(c)** Maximum decorrelation: This weighting scheme minimizes the volatility of the portfolio based on historical correlation among the individual stocks.
   - **(d)** Maximum Sharpe ratio: This weighting scheme maximizes 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 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 deconcentration. This makes the portfolios less sensitive to the underperformance of one specific factor and enables them to benefit from a higher potential for outperformance over the long run (see Amenc, Aguet, and Goltz 2020 for a detailed discussion). As gaining factor exposures exposes investors to some additional types of risk, the diversified weighting schemes are used in step 3 to reduce the risk and achieve diversification.

Exhibit 8 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, and the sixth combines exposures across various multi-factor scores. Each of these portfolios is 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 few 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 Brute-Force strategies described previously.

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, prioritizing assets that exhibit

EXHIBIT 8

Risk Factors Portfolios across Several Values for the Multi-Factor Score Filter

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

NOTES: Each portfolio contains only 25 assets. The Sharpe ratio for each portfolio is the average of 100 simulated portfolios.

robust exposure to a balanced mix of risk factors, can significantly outperform more generalized investment methods.

Exhibit 8 also shows that by adjusting the intensity of exposure to multi-factor scores, i.e., creating indexes 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 Exhibit 3 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, Exhibit 7 illustrates a comparison among the three Brute-Force diversification strategies. We see that Brute-Force strategies all perform similarly, on average, with 100 assets, whether sector and country diversifications are explicitly considered—this is because, with 100 assets, investors are mechanically exposed to many sectors and countries. The average Sharpe ratio is circa 0.15.[6]

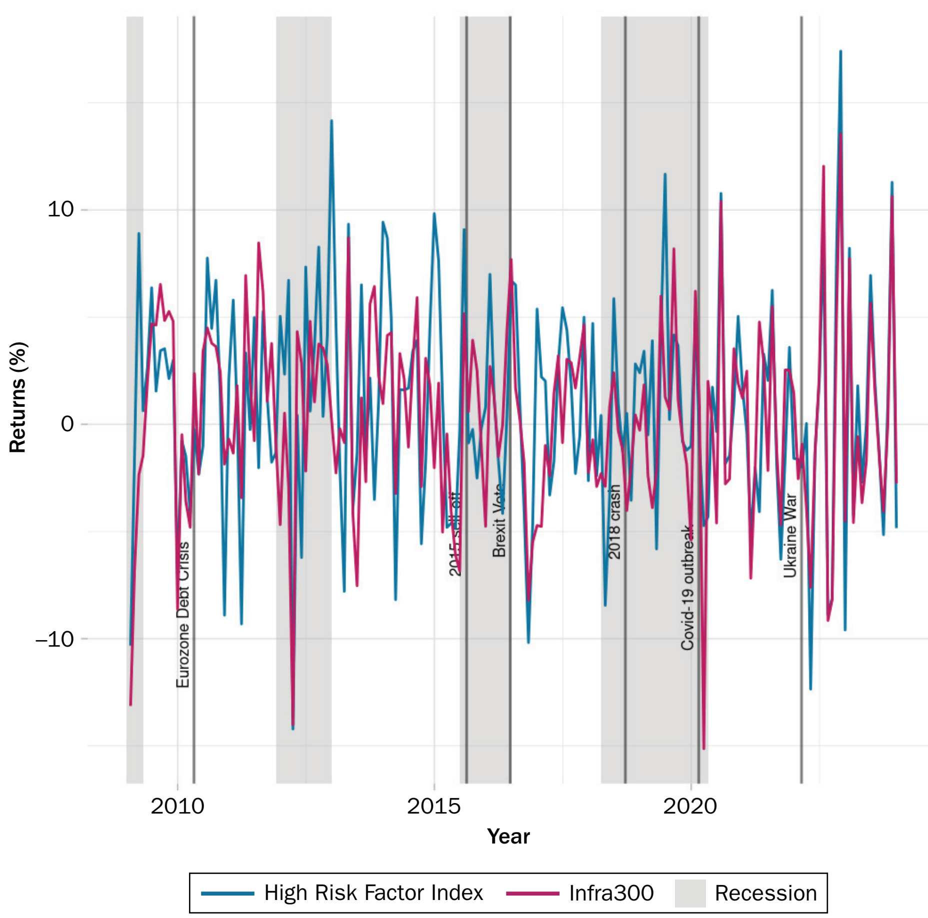
[6]When we change the weighting of the portfolio to using market value weights instead of equal weights our results remain unchanged that the Brute-Force strategies need at least 100 assets to achieve a Sharpe ratio as high as 0.15 as illustrated in Exhibit A1.

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. Using Ordinary Least Squares (OLS), we show in Exhibit A8 in the Appendix that most of the performance of the HFI portfolio is explained by the contribution of leverage, profit, size, and investment risk factors, where leverage and profit account for most of the performance of the HFI index. Thus, a high factor intensity portfolio that has a high Sharpe ratio can be built by aggregating factor exposures.

This suggests that a focused approach, prioritizing 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 demonstrate 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 Exhibit 9, which shows the monthly time series of the high risk factors index over

EXHIBIT 9
High Risk Factors Index



NOTES: Correlation between the two series is 0.63. The shaded areas represent the OECD recession periods. The vertical black lines represent financial and policy shocks.

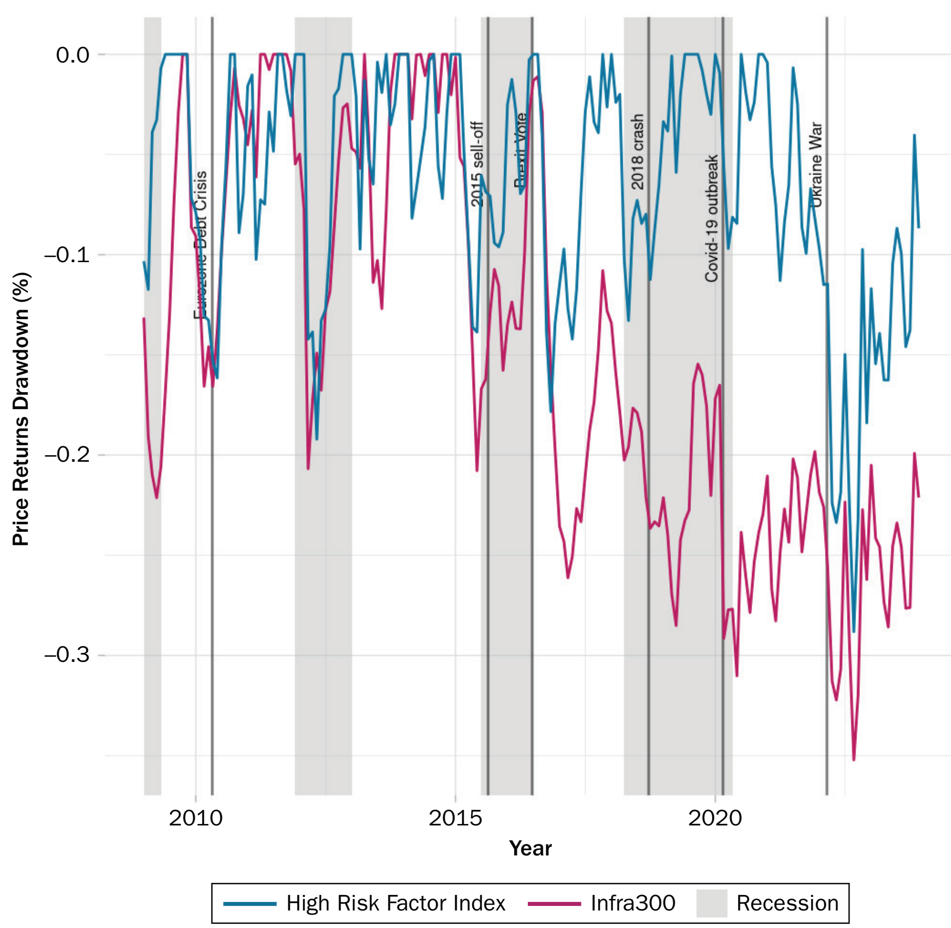
the period 2009–2023, along with the broad market infra300 capital weighted index (weights capped at 5%), which tracks 300 assets in 15 sectors and 20 countries. Although both series have similar co-movements over time, the positive and negative shocks are more nuanced for the high risk factors index than for the infra300. This can be attributed to the infra300's strategy of distribution across all 300 assets, in contrast to the high risk factors index's selective allocation focused on assets with a particular risk profile.

We also display the maximum drawdown for both indexes in Exhibit 10. As displayed, the HFI index exhibits fewer drawdowns than the infra300 index. This proves that the risk factors diversification, along with the weighting scheme used to construct the HFI index, make it more resilient to drawdowns than the infra300 index showing diversification through concentration. This confirms the findings of Aguet, Amenc, and Goltz (2019) that the HFI Diversified Multi-Strategy smart factor index outperforms its cap-weighted counterparts.

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

EXHIBIT 10

Price Return Drawdowns Monthly CW Infra300 vs. High Risk Factors Index for the Period 2009–2023



NOTES: Both indexes are measured in USD. The shaded areas represent the OECD recession periods. The vertical black lines represent financial and policy shocks.

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 indexes. We add infrastructure to the portfolio and consider the implications using different optimization approaches: return targeting, risk targeting, and equal risk contribution.

Approach

For this analysis, we follow Amenc, Blanc-Brude, and Gupta (2022a) 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 20:80 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 60:40 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. Exhibit 13 shows the risk and return associated with each profile. The conservative investors have an annualized expected return and volatility of 4.98% and 7.4% respectively, while the aggressive investors have an 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 optimization, a return-targeting and a risk targeting optimization, as well as a risk-only optimization technique.

- Return targeting: This strategy is based on finding an allocation that achieves a portfolio return greater than or equal to a fixed target, while minimizing the portfolio risk. The return target is greater than or equal to the 60:40 and 20:80 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 indexes 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 maximizing returns.
- Equal risk contribution (ERC): This strategy is based on finding the optimal portfolio weights to minimize the risk contribution from all asset classes, while minimizing the Effective Number of Constituents or ENC. Illiquid assets have a maximum weight of 20%.

EXHIBIT 11

Average Industry Expectations of Risk and Return across Different Asset Classes

Asset Class	Return	Risk	Sharpe Ratio
High risk factors index	10.03%	19.19%	0.588
Infra300	10.5%	10.97%	0.683
Brute-Force 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

NOTES: 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 diversified weights. Brute-Force 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 annualized returns. The Sharpe ratios are calculated with an assumption of risk free rate of 0%. Results are in USD.

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

- ENC is at least six.
- The allocation to all illiquid assets (real estate, private equity, hedge funds, commodities, risk factors indexes) does not exceed 20% of the portfolio, leaving at least 80% invested in liquid assets.[7]

Inputs: Forward-Looking Data

We use forward-looking data as inputs to investigate the role of unlisted infrastructure equity in a multi-asset portfolio allocation. 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 organization is available in the appendix, in Exhibits A9 and A10, and their average estimates are presented in Exhibit 11.

For infrastructure, we use the expected returns estimated by the EIPA pricing model. The EIPA indices are driven by a valuation methodology that is based on estimating the market expected returns at each point in time, using the latest primary and secondary market transaction prices. On monthly basis, the market discount rates of hundreds of equity investments are estimated by updating the EIPA multi-factor model of expected returns, given (1) what the estimates were until then, and (2) how new market price data suggest they have evolved since the last estimation (Amenc et al. 2022b).[8]

For the high risk factors index (HFI), our smart Infra methodology resulted in having an index that consists of 35 assets and is tilted toward factors that offer higher returns, such as size, leverage, profitability, investment, and term spread. As before, the diversified multi-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

[7] The choice of 20% is ad hoc but consistent with average allocations for some large institutional investors such as US public pension funds.

[8] The EIPA pricing model is a function of three components, the future stream of dividends, the term structure of risk-free rates, and a risk premium calculated based on the asset specific systematic risk factors. Although unlisted assets could suffer from smoothing of returns and volatility (Anson 2024), the EIPA pricing model prevents the artificial smoothing of returns, offering a fairer and more transparent estimate of their true economic value.

EXHIBIT 12

Infra Correlations Are Based on Long-Term In-Sample Data from 2009 to 2019

	Equity	Emerging Equity	Corp. Bonds	Gov. Bonds	Real Estate	Private Equity	Hedge Funds	Commodity	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

NOTES: 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.

EXHIBIT 13

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%

EXHIBIT 14

Optimal Allocation with Return-Targeting Approach under Different Risk Targets

	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

NOTES: For top 10% HFI, the high risk factors index includes 35 assets across different sectors and geographic locations. Sharpe ratio is calculated based on 1% risk free rate. All calculations are in USD.

and macroeconomic risks. The high risk factors (HFI) index created includes companies from nine countries and all the TICCS® Industrial superclass sectors.

RESULTS

Return Targeting

The results of the optimization problem showing the detailed weights and the portfolio performance for each type of investor, across different filtering for the risk factor indexes for the risk targeting technique, are displayed in Exhibits 14 and 15.

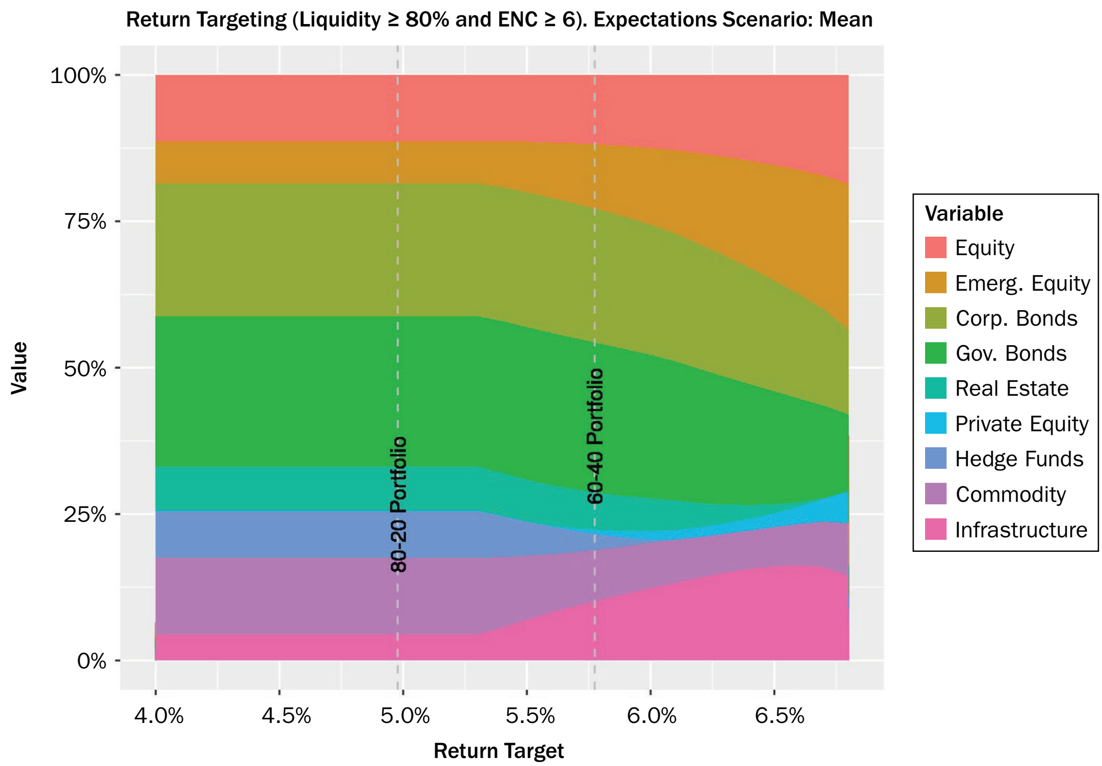
The two investor profiles are found to have a positive allocation to infrastructure, ranging from 4.4% to 9.2%. For each profile, the risk factor indexes have greater weights than other private asset classes such as real estate, private equity, and hedge funds. This can be explained by the performance of this index in Exhibits 11 and 12 because infrastructure generates the highest return and risk-adjusted return, as well as the lowest correlation with other asset classes.

Risk Targeting

The results of the risk targeting optimization are displayed in Exhibits 16 and 17. We implement this exercise using a range of volatility targets, ranging from 6.5% to 12%, which span all possible portfolio volatilities under the pre-defined constraints. A conservative investor's portfolio has a portfolio volatility of 7.4%; an aggressive investor has a portfolio volatility of 11.8%.

EXHIBIT 15

Optimal Allocation with Return-Targeting Approach under Different Return Target Constraints



NOTE: Infrastructure is the high risk factors index constructed using the Smart Infra approach.

EXHIBIT 16

Optimal Allocation with Risk-Targeting Approach under Different Risk Targets

	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

NOTES: For top 10% HFI, the high risk factors index includes 35 assets across different sectors and geographic locations. Brute-Force Index is created with 10 infrastructure assets chosen at random. Sharpe ratio is calculated based on 1% risk free rate. All calculations are in USD.

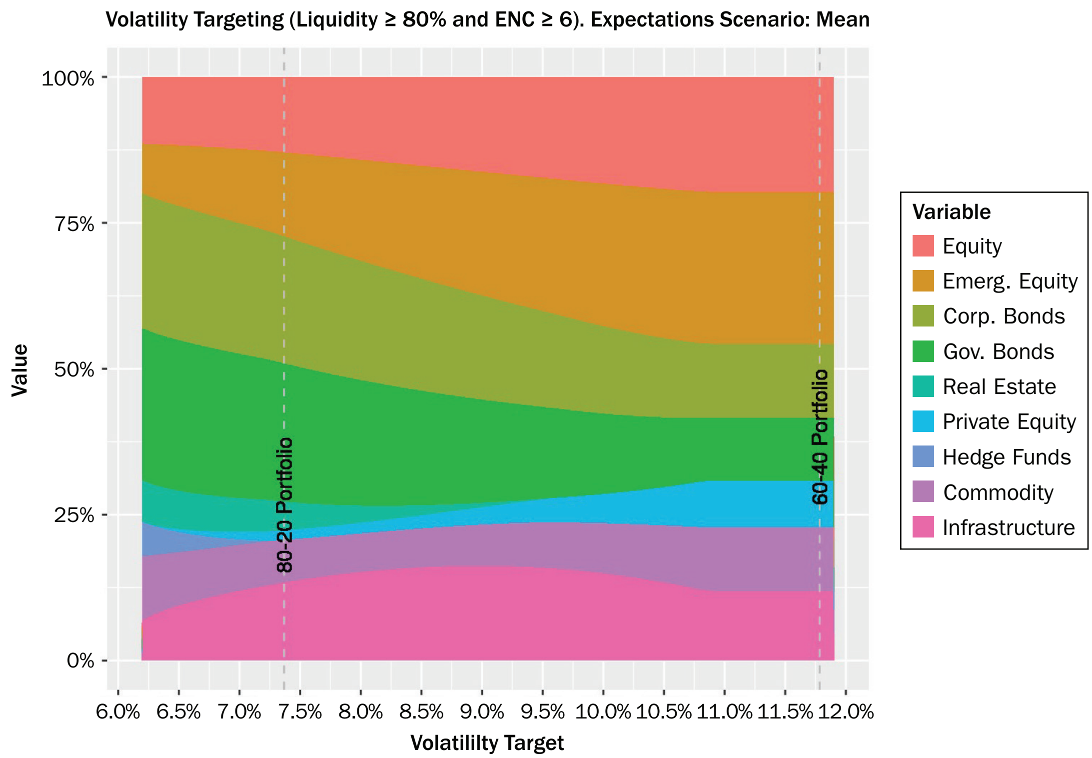
As the risk appetite of the investors becomes more aggressive, the proportion of their holdings in fixed income and infrastructure shrinks as they switch into riskier asset classes such as equities, real estate, and private assets. For instance, in a 20:80 portfolio, there is no private equity. However, the infrastructure indexes are always present regardless of whether investors 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.

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 optimization problem are displayed in Exhibits 18 and 19 show the results for varying ENC targets for three specific cases: low (5), medium (6), and high (7) ENC target.

EXHIBIT 17

Optimal Allocation with Risk-Targeting Approach under Different Risk Target Constraints



NOTE: Infrastructure is the high risk factors index constructed using the Smart Infra approach.

EXHIBIT 18

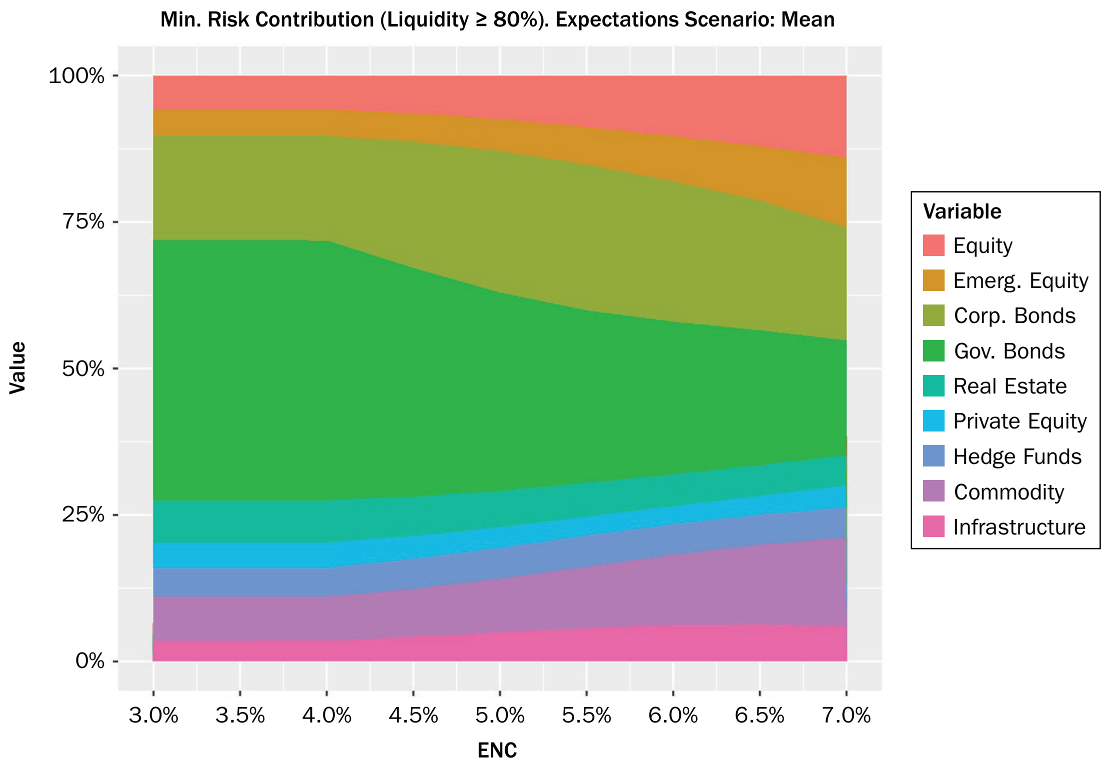
Optimal Allocation Using Equal Risk Contribution Approach under Different ENC Targets with the Top 10% HFI High Risk Factors Index

	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

NOTES: Sharpe ratio is calculated based on 1% risk free rate. All calculations are in USD.

EXHIBIT 19

Optimal Allocation Using Equal Risk Contribution Approach under Different ENC Targets



NOTE: Infrastructure is the high risk factors index constructed using the Smart Infra approach.

EXHIBIT 20

Sharpe Ratio Comparison across Portfolios with High Risk Factors Index and without Infrastructure Assets

	Return Targeting		Risk Targeting	
Allocation	20/80	60/40	20/80	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

NOTES: Sharpe ratio is calculated based on 1% risk free rate. All calculations are in USD.

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 minimize the risk contributions. As the ENC target increases, the weights of other asset classes must increase 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 decreases when moving from 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.

These results illustrate, across three different portfolio optimization 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.

Exhibit 20 presents a comparison of Sharpe ratios across different portfolio strategies with and without infrastructure. The portfolios that incorporate infrastructure assets consistently achieve higher Sharpe ratios. This confirms the positive role that infrastructure can play in the portfolio. Similarly, Exhibit 21 presents a comparison between the HFI portfolio and Brute-Force portfolio that includes 35 randomly chosen assets. For both portfolios, we show that the portfolios with

EXHIBIT 21

Portfolio Allocation and Sharpe Ratio Comparison across Portfolios with High Risk Factors Index and Brute-Force Portfolio with 35 Randomly Chosen Assets

	Return Targeting		Risk Targeting	
Investor Profile	**20/80**	**60/40**	**20/80**	**60/40**
Strategic Asset Allocation with HFI				
Allocation to infra	4.40%	9.20%	13.10%	12%
Sharpe ratio	0.706	0.717	0.690	0.537
Strategic Asset Allocation with Brute-Force Assets				
Allocation to infra	3.42%	9.24%	10.27%	9.40%
Sharpe ratio	0.683	0.669	0.660	0.506

infrastructure investments have a significant weight in the portfolio allocations, however, the Sharpe Ratio is always higher with HFI portfolio as compared to the Brute-Force approach.

CONCLUSION

This article 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 (Brute-Force) approach of adding more assets, sectors, and geographies is a very inefficient and expensive way to diversify. This approach 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 be 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 Brute-Force 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 genuine strategic access to the asset class, rather than just making very active bets on a few assets. Although 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 optimization 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 article.

The differences in return volatility and correlation among 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 multi-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 article. Hundreds of bets can be necessary to build a portfolio with fully diversified idiosyncratic risks, unless these assets are selected based on 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 article. 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 as, “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.

Finally, the principles of risk factor diversification illustrated here demonstrate that in private markets, where investors are restricted to holding a limited number of assets, investors can achieve diversification through concentration. Our approach is not limited to unlisted infrastructure equity alone, but can be extended to other illiquid asset classes such as infrastructure debt, real estate, and private equity. By applying similar strategies, investors can leverage the benefits of systematic risk factor exposure to achieve more efficient diversification, thereby enhancing portfolio performance and mitigating idiosyncratic risks across a broader range of investments.

APPENDIX

EXHIBIT A1

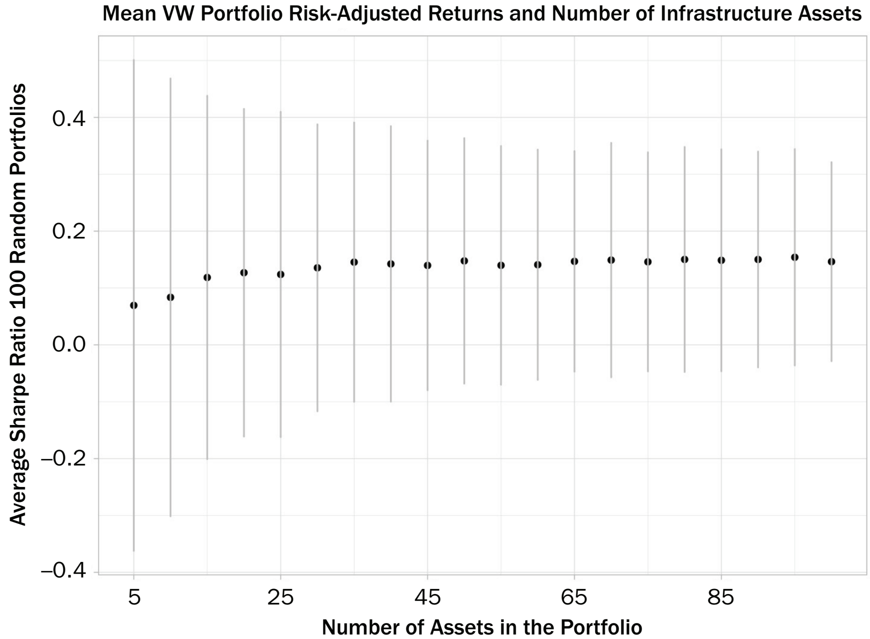
Comparison of the Three Brute-Force Diversification Strategies with 100 Assets from 100 Simulated Portfolios and Risk Factors Diversification Based on 100 Simulated Portfolios of 25 Assets

	100 Assets Brute-Force Strategy	100 Assets & 12 Sectors	100 Assets & 12 Countries	High Risk Factors Portfolio with 25 Assets
Annualized return	2.85%	2.8%	2.95%	7.6%
Annualized risk	12.6%	12.6%	13%	18.5%
Sharpe ratio	0.146	0.144	0.150	0.357
[Up, Lo bound]	[–0.029, 0.321]	[–0.001, 0.289]	[–0.085, 0.385]	[0.173, 0.540]

NOTES: Brute-Force strategies are based on Value Weighting. Results are in USD.

EXHIBIT A2

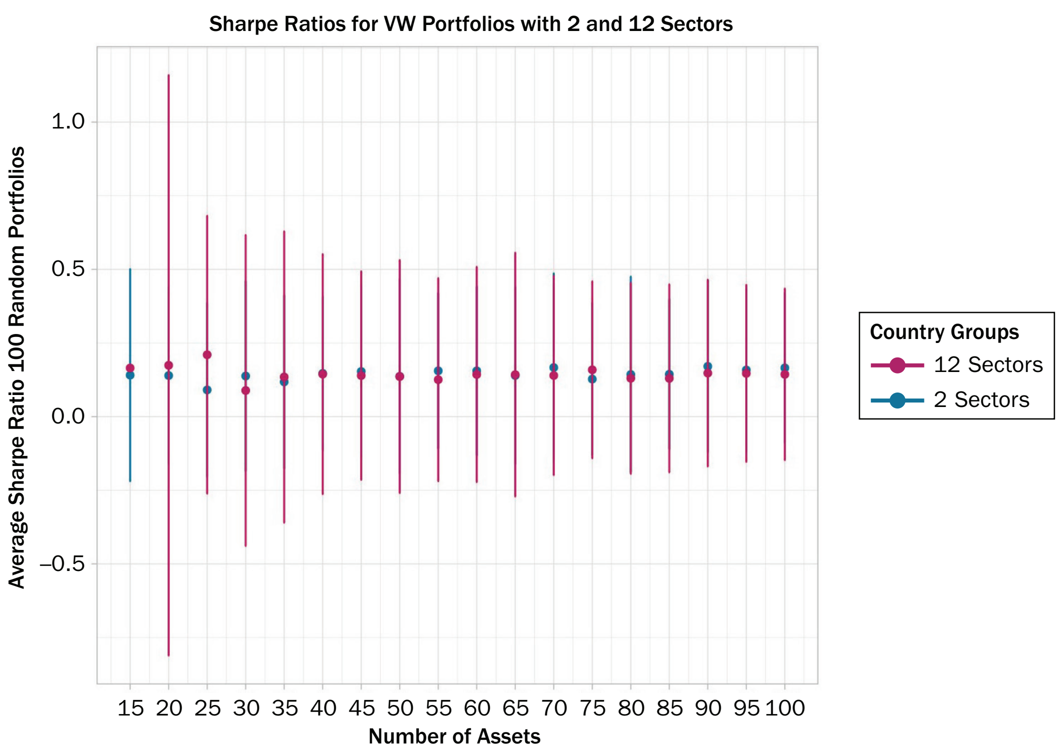
Average Sharpe Ratio of 100 Random Value Weighted Portfolios for the Brute-Force Diversification by Number of Assets



NOTE: The error bars represent the 95% confidence interval for the Sharpe ratios in the portfolio simulations.

EXHIBIT A3

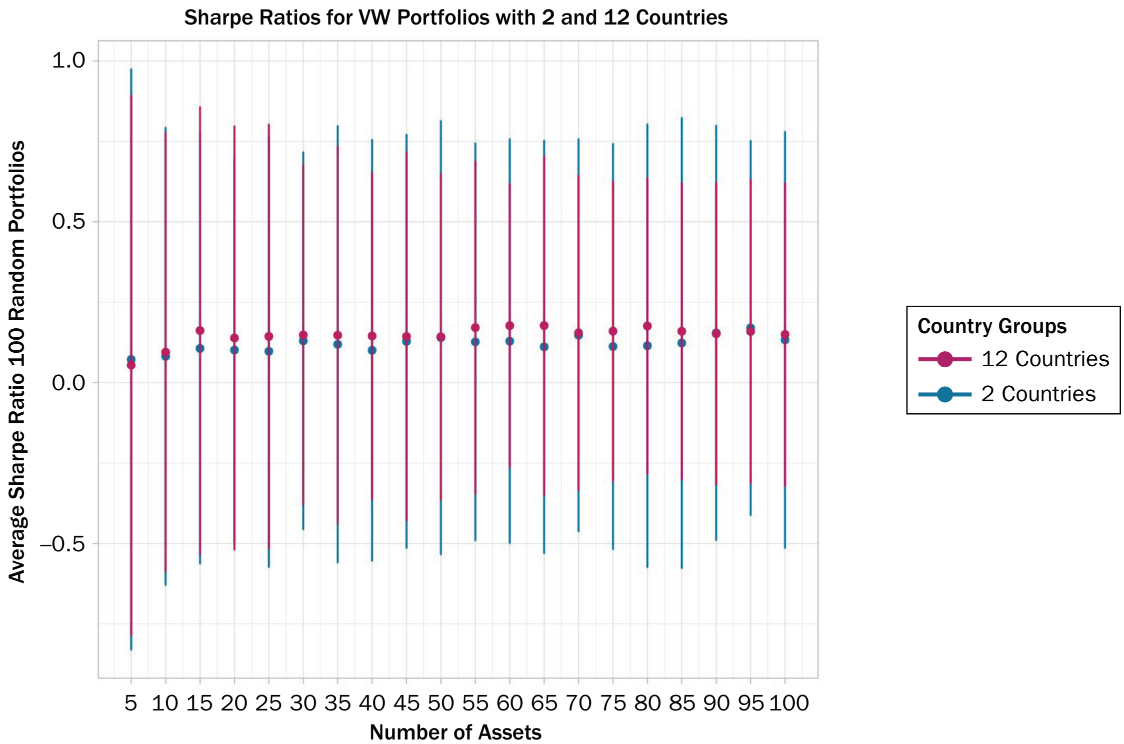
Brute-Force Diversification by Country, Value Weighted Portfolios, Risk-Adjusted Return



NOTE: The red and blue bars represent the 95% confidence interval for the Sharpe ratios in the simulations for the 2 and 12 countries portfolios respectively.

EXHIBIT A4

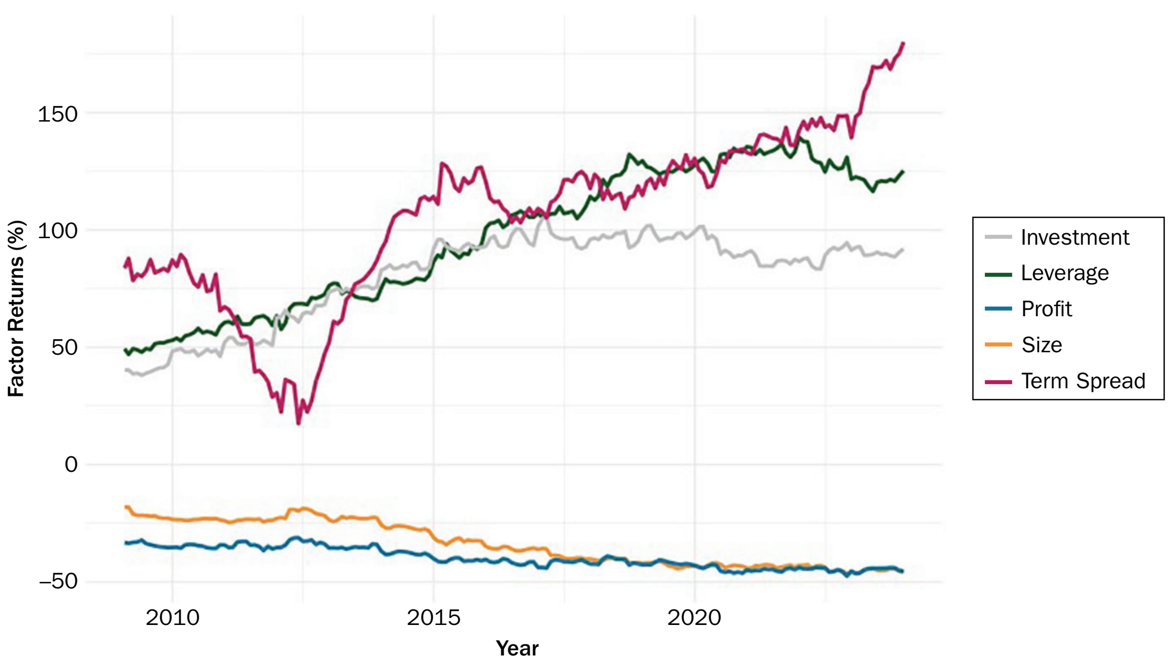
Brute-Force Diversification by Country, Value Weighted Portfolios, Risk-Adjusted Return



NOTE: The red and blue bars represent the 95% confidence interval for the Sharpe ratios in the simulations for the 2 and 12 countries portfolios respectively.

EXHIBIT A5

Unlisted Infrastructure Equity Risk Factor Returns



NOTES: 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.

SOURCE: InfraMetrics.

EXHIBIT A6

Unlisted Infrastructure Equity Risk Factor Returns

	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

NOTE: Market Factor Return is the average return across all companies.

SOURCE: InfraMetrics.

EXHIBIT A7

Risk Factors—Exposure for Global Infrastructure

	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%

SOURCE: InfraMetrics.

EXHIBIT A8

Single Indexes Factor Contributions to the HFI Portfolio

HFI Portfolio	Capital Return Contribution (beta)	SE	p-Value
Size factor	0.178	0.06	***
Leverage factor	0.331	0.05	***
Investment factor	0.078	0.03	***
Profit factor	0.303	0.05	***
Term spread factor	0.027	0.02	
Constant	–0.0004	0.001	
Adj-R^2	94%		

NOTES: Factor effect obtained by regressing individual high factor intensity portfolios against the multi-factor intensity portfolio. Data from 31/03/2009 to 31/12/2023. USD price returns.

EXHIBIT A9

Expected Returns Estimates from Leading Asset Managers and Consultants

	Black Rock	JP Morgan	Mellon	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%

EXHIBIT A10

Expected Risk Estimates from Leading Asset Managers and Consultants

	Black Rock	JP Morgan	Mellon	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%	9.00%	5.50%	8.45%	NA
Commodity	NA	18.00%	16.00%	NA	15.30%	23.80%	14.30%	17.10%	18.00%	16.02%

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