A Publication of the EDHEC Infrastructure Institute-Singapore

# Private Infrastructure Broad Market Equity Indices

## Benchmarking Europe's Private Infrastructure Equity Investments 2000-2016

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# Foreword

The purpose of this publication, "Private Infrastructure Equity Index: Benchmarking Private European Infrastructure Equity 2000-2016," the first publication drawn from the Long-Term Infrastructure Investors Association (LTIIA) research chair at EDHEC Infrastructure Institute-Singapore, is the result of an ambitious project to create investment benchmarks for long-term investors in infrastructure.

This effort started in 2013 with EDHEC research sponsored by Meridiam and Campbell-Lutyens that laid the theoretical and technical groundwork of an approach that would take into account the characteristics of private infrastructure equity.

This work provided significant advances in two areas. First, it contributed a definition of "infrastructure investment" rooted in the theory of contracts and *regulation economics*. Infrastructure is meant to perform a series of industrial functions (transportation, distribution, etc.) But this intuitive, I-know-it-when-I-see-it, industrial definition does not translate directly into one of infrastructure *investment*.

Focusing on the underlying economics was essential to arrive at a definition that made sense for investors and regulators. In this respect, the recommendations made by EIOPA with respect to qualifying infrastructure assets under Solvency-II in 2016 were an important outcome of the work done at EDHEC.

The second important contribution concerned measuring the risk-adjusted performance of long-term private equity. The combination of advanced statistical techniques to forecast future payouts and volatility with a discount factor *term structure* taking into account the evolution of the risk profile, addressed the short-comings of the old NAV/IRR perspective commonly used in the private equity sector.

This approach benefits asset owners who can now access uninversal metrics like the Sharpe ratio. Managers also benefit because IRR computations underestimate a substantial proportion of the long-term performance generated by capital gains. With this approach, the ability of infrastructure investors to *genuinely* create long-term value is at the centre of the valuation framework.

We are grateful to the members of LTIIA for their support. Two in particular have contributed prominent support to this project: Campbell-Lutyens and the Long-Term Investors Club, which represents the major public development banks of the G20.

**Noël Amenc**

Associate Dean, EDHEC Business School

# About the Authors

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# Executive Summary

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This paper presents the first results of an ambitious applied research project to create and compute fully fledged **private infrastructure equity investment benchmarks**.

The indices we created span 14 European countries over 16 years, going back to 2000. They are built from a representative sample by size and vintage of the investable private European infrastructure market, and they include hundreds of firms over that period.

In this paper, the first using the EDHEC*infra* equity benchmarking database and technology, we focus on three questions:

1. How does a "broad market" index of private infrastructure equity investments perform relative to a public equity market reference index?
2. Is there a difference between the risk-adjusted performance of the three typical infrastructure business models (Blanc-Brude, 2014)–contracted, merchant, and regulated infrastructure–or between investing in "project finance" vehicles and "infrastructure corporates"?
3. How much diversification of investment-specific risk can be achieved in portfolios of private infrastructure equity investments?

The first two questions have been at the centre of the recent debates on the definition of an "infrastructure asset class," be it for asset-allocation or prudential purposes.

The third one is essential to better understanding how asset owners and managers can aim to access this asset class and not be limited to a few large, active bets (alpha), thus contradicting recent paradigm shifts in asset and risk management, including the twin objectives to focus on passive investing and remunerated risk factors (betas).

## Building a Representative Sample of the Private Infrastructure Market

Empirical research in finance on private or unlisted investment often suffers from multiple biases created by the various sources of data available. If private data is contributed solely by a limited group of managers and investors, it is likely to overrepresent the better, larger investments and very unlikely to represent the structure of the investable market in terms of country and sector distribution.

To avoid such biases, when selecting index constituents and collecting data, we take a bottom-up approach:

1. Given a region and its core countries, we first document the structure of the investable infrastructure sector in each national market. This includes documenting how investors might become the owners of either individual project companies or special-purpose vehicles (SPVs), or of firms that operate in a limited group of industrial sectors and focus narrowly on the provision of infrastructure-like services. These include ports, airports, firms engaged solely in

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energy distribution, water treatment and distribution, or other activities typically understood to correspond to "infrastructure";

2. We identify which broad categories each identified firm belongs to (i.e., sector, type of corporate structure, and business model);
3. We then build a representative sample for the whole region in line with country, sector, corporate structure, and business model distribution of all investable infrastructure firms (an approach known a *stratified sampling*).

Thus, we avoid creating biases in the data collection by overweighting data made available by any one contributor.

Once the relevant firms have been identified, in a second step, the relevant data is collected for a representative sample of the investable universe for which the best data can be collected. Hence, the use of data contributed by private investors is maximised but without creating sampling biases. For all other individual firms in the sample, we collect the relevant data from a range of public and private sources, including audited financial accounts, freedom-of-information requests, commercial databases, etc.

Detailed financial information is collected for all firms in the market sample, from their incorporation date to year-end 2016 or their date of cessation of operations.

Following the EDHEC*infra* template, we collect data about each firm and each debt instrument identified as part of its capital structure. Firms are also the subject of a number of *events*,[1] firms and instruments also have individual *attributes*,[2] and they are also attached to *values* (see Blanc-Brude et al., 2016, for a detailed discussion).

This data is collected from multiple sources and aggregated, cross-referenced, analysed, and validated by a series of algorithms and a team of human analysts. Each firm's data is reviewed iteratively at five different levels of validation including computer-generated and human checks.

Over the 15-year period of this study, our market sample consistently represents at least 50% of the total asset book value of investable infrastructure firms in Europe, ensuring a significant degree of market coverage of the broad market index.

## A Fully Fledged Performance Measurement Technology

Private infrastructure firms are seldom traded, and only a limited amount of market price data is available to observers.

Hence, the risk-adjusted performance of the equity invested in each firm in the index sample is derived by forecasting cash flows or payouts to the equity holders, including any shareholder loans, fees, etc., and discounting them on the basis of 1) the volatility of future payouts forecast at time *t*, 2) duration (i.e., the remaining life

1 - E.g., incorporation, construction start and completion, operational phase start, defaults, refinancing and restructuring, prepayments, end of investment life, etc.

2 - E.g., for firms, business model, type of regulation, contracted or indexed nature of inputs and outputs, etc.; for instruments, seniority, currency, repayment profiles, interest rates, maturity date, etc.

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of the investment), and 3) available price information in each period (including the initial value of the investment and comparable transactions taking place each year).

Once each equity stake has been valued in each period, the derivation of the relevant risk-adjusted performance metrics at the asset level is straightforward.

Individual assets are then combined to represent the performance of a given portfolio or index.

To implement this approach, a number of building blocks are needed:

1. A model of the "free cash flow to equity" (FCFE) until the end of the investment life or the next 50 years, whichever is shorter, is implemented using information about the firm's revenues, capital, and operating costs, as well as its capital structure, debt service cover ratio, and future debt service;
2. The mean and variance of each firm's FCFE "retention rate" or RR (i.e., cash at bank / FCFE), is estimated in all realised periods, and a forecast is made for the remainder of the firm's life. In other words, the firm's RR is treated as an unobservable stochastic process, the parameters of which we estimate over time;
3. The combination of the forecast of the mean and variance of FCFE and RR allows computation of a stream of expected equity payouts and conditional (future) payout volatility;
4. Firms are grouped by risk "clusters" or buckets as a function of their payout volatility and time to investment end (a proxy of duration);
5. Within each risk bucket, a term structure of discount factors (and its range) is derived, reflecting the value of the investment relative to expected payouts and conditional payout volatility and duration, as well as any relevant and observable market prices (primary and secondary transactions) in each year in the same risk cluster;
6. Finally, after individual performance metrics have been obtained for each firm's senior debt, a return covariance matrix is estimated for each index, and individual assets are aggregated following preset inclusion and rebalancing rules.

## Six Key Indices

Current segmentation options allow computation of 192 different combinations of our European infrastructure equity indices. In what follows, we focus on the following six key indices for the 2000-2016 period:

1. A **broad market infrastructure index**, covering 14 European countries and six industrial sector groups, includes 330 "live" firms in 2016, with a capitalisation of EUR293.5bn. Over the period, 398 firms have been included in the index;
2. A **private infrastructure project equity index** for the same geography, including

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235 live firms in 2016 for a capitalisation of EUR68bn (257 firms over the period);
3. An **infrastructure corporate equity index** with a EUR225.5bn capitalisation in 2016 for 95 live firms (103 firms over the period);
4. A **contracted infrastructure equity index** with 195 live constituents in 2016 or EUR47.2bn of capitalisation in 2016 (204 firms over the period);
5. A **merchant infrastructure equity index** including 70 live firms and a total capitalisation of EUR75.2bn (86 firms over the period);
6. A **regulated infrastructure equity index** with 65 live 2016 constituents and representing EUR171bn of capitalisation (70 firms over the period).

Index constituents that have been included in the index at one point may have been removed from the "live" 2016 index because they reached minimum size threshold, went bankrupt and were liquidated, or were sold and merged following an event of restructuring.

In order to best capture any infrastructure-specific effects, we focus on the so-called fully hedged version of each index, which ignores the impact of foreign exchange movements on returns.

Each set of index constituents can be broken down by infrastructure "business model," currency, country of origin, industrial sector, or corporate structure.

Figures 1, 2, and 3 show the composition of the broad market infrastructure equity index by country, sector, and business model, on a value-weighted and equally weighted basis.

## Private Infrastructure Equity Investments Outperform the Market

Turning to our results, we can draw out a number of stylised facts with respect to our first two questions about the risk-adjusted performance of private infrastructure equity:

1. Our broad European market infrastructure equity index (including project and infrastructure corporates) significantly outperforms the European public equity reference index over the 2000-2016 period;
2. It also does not suffer from any drawdown during the 2007-2008 and 2010-2011 periods of stock market collapse, as shown on figure 4;
3. This effect is due to the high level of diversification of firm-specific risk within the infrastructure indices. Hence, while we observe numerous cases of losses at the project level, the index as whole maintains a positive performance in each year;
4. Figure 4a shows that it is infrastructure *projects*, rather than corporates that contribute most of the broad market performance;
5. Figure 4b suggests that merchant and contracted infrastructure contributed equally to this outperformance, however this is shown on a value-weighted basis, which tends to overweight larger

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Figure 1: EDHEC*infra* **broad market** infrastructure equity index, 2016, **country** breakdown by market value

(a) value-weighted (b) equally weighted

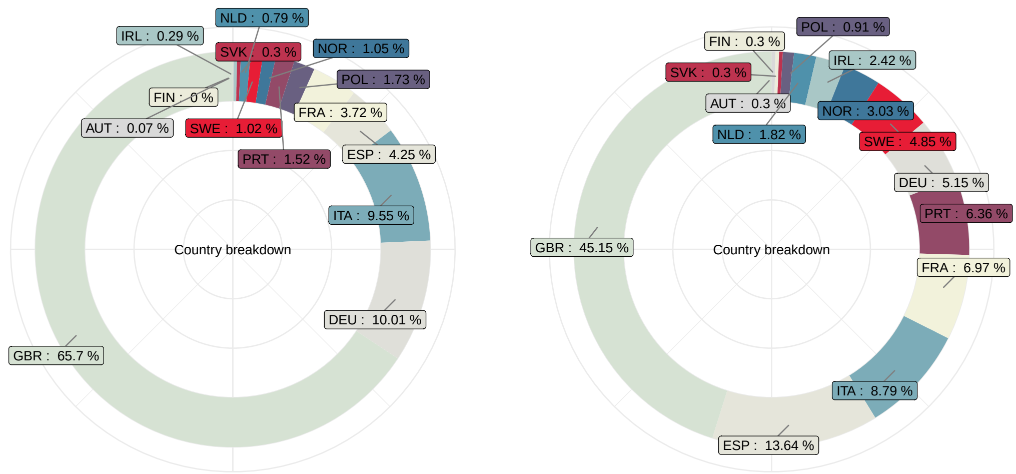


Figure 2: EDHEC*infra* **broad market** infrastructure equity index, 2016, **sector** breakdown by market value

(a) value-weighted (b) equally weighted

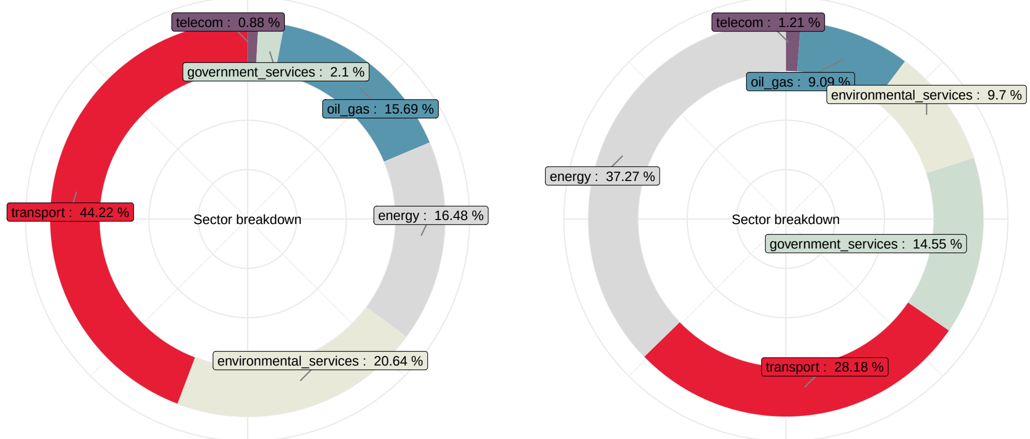

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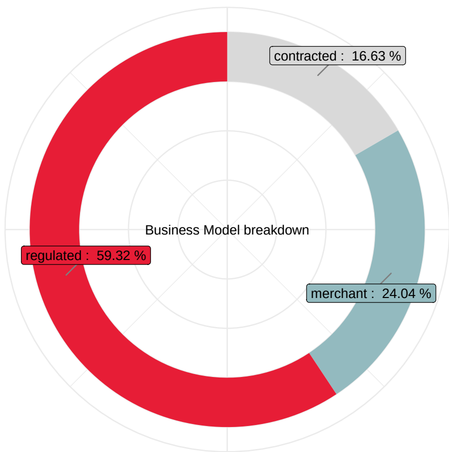
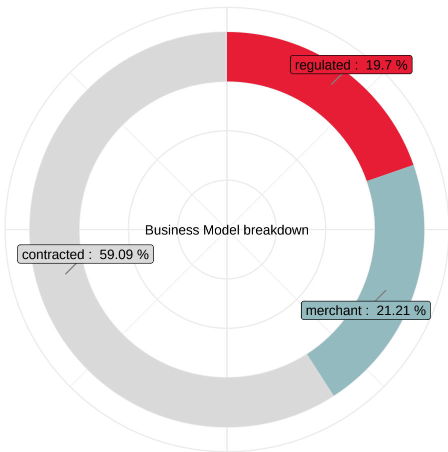
Figure 3: EDHEC*infra* **broad market** infrastructure equity index, 2016, **business model** breakdown by market value

(a) value-weighted




(b) equally weighted




projects. We note that on an equally weighted basis (not shown here), most of the outperformance comes from contracted infrastructure alone;

6. In figure 5, a secular trend of lower internal rates of return (IRRs) is visible, driven by higher equity valuations of private infrastructure firms over the period. We note that infrastructure projects have significantly higher IRRs than infrastructure corporates (figure 5a) and that merchant infrastructure also tends to have higher IRRs than contracted or regulated infrastructure (figure 5b);
7. These IRRs are computed in the usual manner using all realised and forecast equity cash flows for all index constituents. It should be noted that the time-weighted returns computed tend to be higher than the index IRRs. The IRR, which is a money-weighted computation, should really be compared with the value-weighted index returns. The IRR also implies (by design) increasing per-period discount factors, whereas we estimate a term structure of discount factors which reflect the derisking of infrastructure investments over time. As a result, reported time-weighted returns include a share of expected capital appreciation, which the standard IRR formula cannot capture.

Tables 1 and 2 provide more details about the risk-adjusted performance of private infrastructure equity for projects and corporates at different horizons, on a value-weighted and equally weighted basis, respectively.

Our broad European market private infrastructure equity index compares favourably to a public equity reference index. It provides greater performance and lower

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risk, including lower value-at-risk (not shown here). As a result, it exhibits an attractive risk-reward profile.

Moreover, certain segments of the private infrastructure universe have contributed most of this performance, namely, infrastructure projects, and contracted infrastructure.

The latter two often overlap, and as well as corresponding to a relatively lower-risk business model, they tend to be smaller in size than other infrastructure firms. Hence, indices built with such assets tend to diversify better and faster. This effect leads to higher returns and lower portfolio risk measures.

## But Achieving Sufficient Diversification Is What Investors Should Be Focusing On

Our third question was concerned with the role of diversification in private infrastructure investment portfolios.

Diversification is always desirable, but it can come at a cost when assets are bulky, deal times long and uncertain, and fixed transaction costs high. As a result, most infrastructure funds make between 6 and 12 investments in their lifetime, and asset owners favouring so-called direct investment, tend to do large transactions and to own between a dozen and a few dozen infrastructure assets (see Blanc-Brude, 2013, for a discussion).

Having built broad market indices including hundreds of assets in some cases, we can now observe the impact of diversification on infrastructure portfolios of various sizes and degrees of concentration.

We can also observe the difference between two ideal-type weighting schemes: on a value-weighted basis, the index represents "the market" in the standard acceptance of the term; on an equally weighted basis, each constituent makes exactly the same contribution to index performance at all times.

Today, neither of these strategies are accessible to asset owners or managers. Nevertheless, they provide us with a better understanding of the upper and lower limits of what infrastructure investors might expect from greater portfolio diversification.

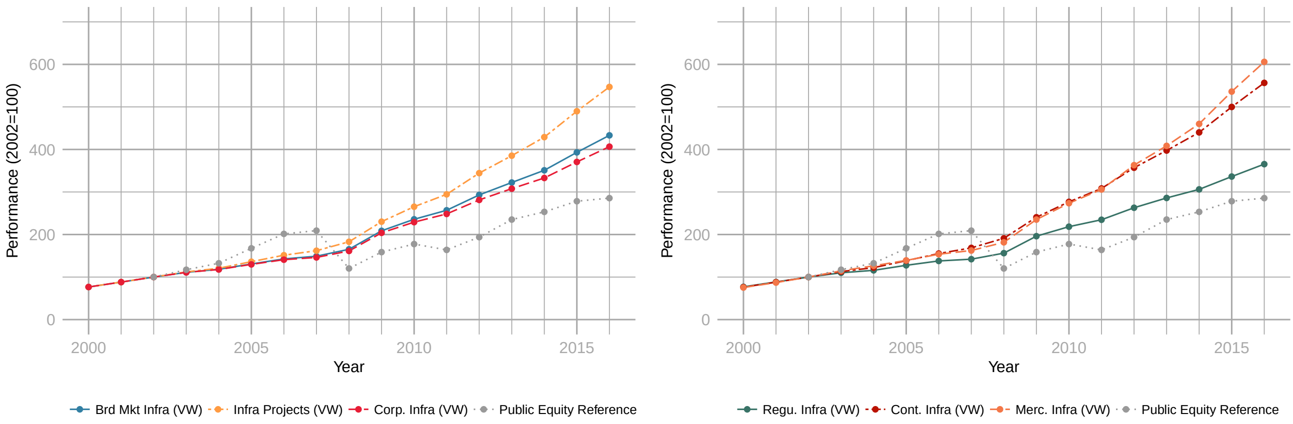
Figure 6 shows the distribution of asset-level return volatilities over the entire observation period. We note that the asset-level volatilities we measure are not "smoothed" [3] and can in fact be quite high, sometimes higher than 100%. Indeed, one of the results of our cash flow modeling and forecasting for equity investors is that infrastructure equity payouts are quite variable both in size and frequency.

Instead, risk measures are considerably reduced at the index level, due to the highly idiosyncratic nature of the volatility of infrastructure assets. Hence, as assets are aggregated in value-weighted and equally weighted portfolios, the average level and

3 - A frequent issue with private investment studies, due to the stale pricing problem (see Woodward, 2004, for a literature review and discussion in the context of private equity.)

Figure 4: EDHEC*infra* equity indices, cumulative performance, value-weighted, 2000-2016

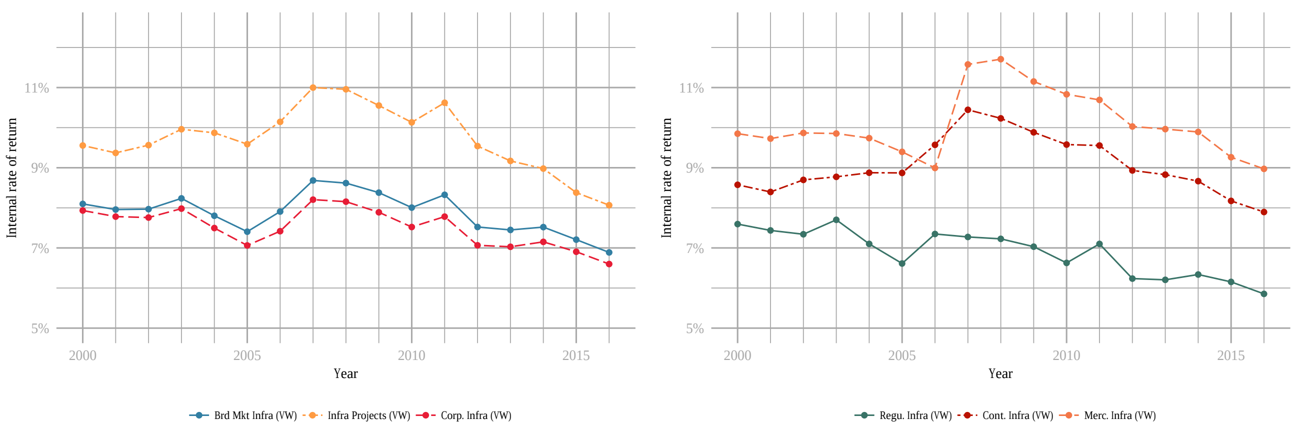
(a) broad market and by corporate structure | (b) by business models




*Public equity reference: Scientific Beta developed Europe cap-weighted index

Figure 5: EDHEC*infra* equity indices, internal rate of return, 2000-2016

(a) broad market and by corporate structure | (b) by business models




the dispersion of portfolio risk measures are considerably reduced.

Figure 7 shows the relationship between the "effective number of bets" or ENB[4] of each of the 192 EDHEC*infra* private infrastructure equity indices in 2016 and the standard portfolio risk measure of each index, which combines the weighted return volatility of each index constituent with a pair-wise covariance matrix of asset returns.

In value-weighted portfolios, the ENB is lower than the number of portfolio constituents. In an equally weighted portfolio, by design the ENB must be equal to the number of constituents.

Figure 7 confirms that the impact of diversification on the portfolio risk measure is significant, and that the higher Sharpe ratios achieved by contracted and project indices as well as equally weighted indices are the result of lower risk measures

4 - A measure of portfolio concentration equal to the inverse of the Herfindahl-Hirschman Index, that is, the sum of squared weights (see Meucci et al., 2013).

Figure 6: Density plot of asset-level and index-level volatilities 192 EDHEC*infra* equity indices, 2000-2016

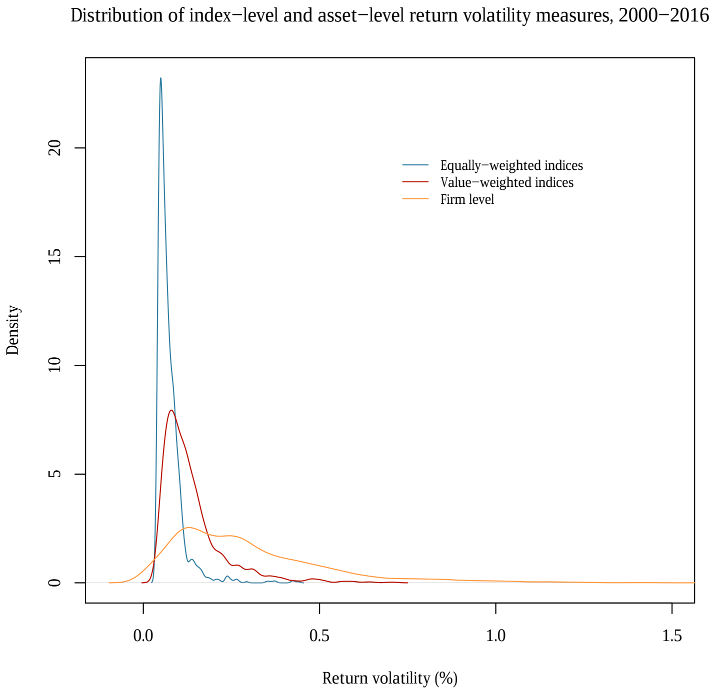



Figure 7: Effective number of bets and portfolio risk measure in 192 EDHEC*infra* equity indices, 2016

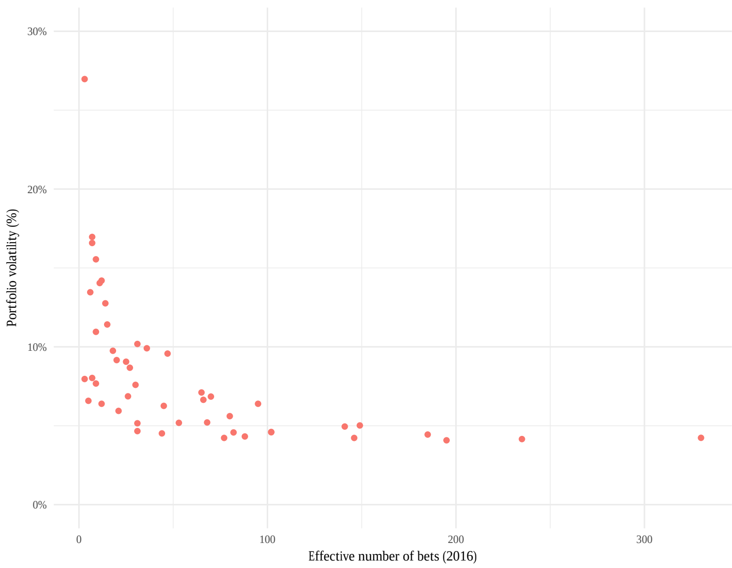


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Table 1: Private infrastructure equity key metrics, broad market, projects, and infrastructure corporates, Europe(14), fully hedged, **value-weighted**

**A) Broad market**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 10.17% | 10.36% | 11.02% | 11.88% | 11.19% |
| Volatility | 9.06% | 8.59% | 8.67% | 9.19% | 10.64% |
| Sharpe Ratio | 1.33 | 1.39 | 1.42 | 1.33 | 1.1 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**B) Infrastructure projects**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 11.65% | 12.39% | 13.2% | 13.8% | 12.78% |
| Volatility | 5.14% | 5.18% | 5.27% | 5.34% | 6.6% |
| Sharpe Ratio | 2.63 | 2.69 | 2.76 | 2.65 | 2.1 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**C) Infrastructure corporates**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 9.69% | 9.72% | 10.37% | 11.32% | 10.78% |
| Volatility | 11.48% | 10.78% | 10.77% | 11.37% | 12.75% |
| Sharpe Ratio | 1 | 1.05 | 1.09 | 1.03 | 0.87 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**D) Public equity market index reference**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 2.62% | 6.73% | 11.96% | 5.72% | 9.59% |
| Volatility | 11.84% | 13.19% | 11.98% | 15.19% | 14.08% |
| Sharpe Ratio | 0.38 | 0.63 | 1.11 | 0.41 | 0.68 |
| Max Drawdown | 0% | 0% | 0% | 42.5% | 42.5% |

*Returns are time-weighted. Volatility is the standard deviation of returns. The Sharpe ratio is equal to excess returns divided by return volatility. In some years, the risk-free rate used to compute excess returns can be negative. Maximum drawdown is the maximum peak to trough in value over the reference period. The public equity index reference is the Scientific Beta developed Europe cap-weighted index (http://www.scientificbeta.com/#/index/WDX-xxxx-wCx). All public market reference metrics are computed using raw data and the same methodologies used for the infrastructure indices.*

achieved through diversification at the portfolio level.

We note that substantial risk reduction appears beyond 50 constituents, a number of assets that few infrastructure asset owners or manager can hope to achieve today.

Indeed, achieving such levels of portfolio diversification is a genuine challenge. Building a large portfolio of infrastructure assets requires a large budget and can take many years.

Moreover, investing on an equally weighted basis, let alone using a more risk-efficient weighting scheme, is virtually impossible, given the heterogeneity of deal sizes and the discrepancy between the illiquidity of individual constituents and the frequent rebalancing requirements of equally weighted schemes.

Still, these results show that achieving only limited levels of portfolio diversification is not a trivial problem for investors. The opportunity cost of not doing so in a private infrastructure equity portfolio may in fact be very large as well.

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Table 2: Private infrastructure equity key metrics, broad market, projects, and infrastructure corporates, Europe(14), fully hedged, **equally weighted**

A) Broad market

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 12.52% | 13.28% | 13.96% | 14.48% | 13.56% |
| Volatility | 4.23% | 4.23% | 4.26% | 4.32% | 4.7% |
| Sharpe Ratio | 3.39 | 3.51 | 3.6 | 3.47 | 2.96 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

B) Infrastructure projects

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 13.55% | 14.42% | 15.09% | 15.47% | 14.45% |
| Volatility | 4.15% | 4.17% | 4.2% | 4.29% | 4.71% |
| Sharpe Ratio | 3.71 | 3.84 | 3.92 | 3.73 | 3.16 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

C) Infrastructure corporates

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 9.99% | 10.44% | 11.15% | 12.13% | 11.65% |
| Volatility | 6.42% | 6.38% | 6.37% | 6.32% | 7.06% |
| Sharpe Ratio | 1.84 | 1.88 | 1.97 | 1.99 | 1.7 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

D) Public equity market index reference

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 2.66% | 8.21% | 14.41% | 7.36% | 12.29% |
| Volatility | 13.25% | 13.27% | 12.39% | 16.71% | 15.5% |
| Sharpe Ratio | 0.34 | 0.74 | 1.27 | 0.47 | 0.79 |
| Max Drawdown | 0% | 0% | 0% | 47.82% | 47.82% |

*Returns are time-weighted. Volatility is the standard deviation of returns. The Sharpe ratio is equal to excess returns divided by return volatility. In some years, the risk-free rate used to compute excess returns can be negative. Maximum drawdown is the maximum peak to trough in value over the reference period. The public equity index reference is the Scientific Beta developed maximum deconcentration (equally weighted) index (http://www.scientificbeta.com/#/index/WDX-xxxx-xDx). All public market reference metrics are computed using raw data and the same methodologies used for the infrastructure indices.*

In the absence of well-diversified infrastructure products, most infrastructure investments thus become very active, concentrated bets, and it becomes much more difficult for investors to have a view on infrastructure investment at the asset-allocation level.

## Tomorrow: The Need for Investable Solutions

With these results, which will continue to be updated and expanded over the coming years, we created the ability to measure the risk-adjusted performance of private infrastructure equity investments on a comparable basis with other asset classes.

This research allows asset owners and managers to begin to evaluate how they might better access infrastructure investments, so that infrastructure investing can become a means to an end and help them meet their investment goals.

The idiosyncratic nature of risk in infrastructure investment is one of the initial appeals of what is called the "infrastructure investment narrative" (Blanc-Brude, 2013): infrastructure businesses are expected to

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exhibit low correlation with the business cycle and help diversify the rest of the portfolio.

But the large and illiquid nature of these investments also creates a significant diversification challenge within the asset class; one that asset owners should not ignore. In effect, the coveted investment narrative, which our broad market indices confirm the existence of, may seem slightly out of reach to most investors if it requires being exposed to hundreds of infrastructure assets.

Delivering the benefits of the infrastructure investment narrative to investors will require the development of new investment products and solutions that can create exposure to a broad base of assets and, at least in part, aim to replicate the characteristics of the infrastructure market.

Full results for 192 indices can be seen at benchmarks.infrastructure.institute/equity/, where you can download index factsheets, data, and constituents.

# 1. Introduction

# 1. Introduction

This paper presents the first results of an ambitious applied research project to create and compute fully fledged private infrastructure equity investment benchmarks.

The impetus to create these indices comes from the financial industry and the need to better understand and document the risk-adjusted performance of a type of alternative investment that has become of increasing interest to institutional investors.

Investors may look to private infrastructure equity in search of yield, diversification, or even liability-hedging (since infrastructure projects have a well-defined duration), but until now they have been unable to fully validate any of these intuitions.

Evaluating the performance of highly illiquid private assets required developing new techniques in the area of academic research in finance.

The project of collecting data, developing the relevant technology, and creating private infrastructure equity benchmarks is a prime example of applied academic research designed to have an impact on real-world business practices all the while being rooted in peer-reviewed scientific research.

These results are the fruits of a significant effort by several research teams of the EDHEC Infrastructure Institute-Singapore to collect and aggregate data, build powerful cash flow models, and implement state-of-the-art asset pricing techniques to derive risk-adjusted performance measures at the individual instrument and portfolio level.

The indices we created span 14 European countries over 16 years, going back to 2000. They are built from a representative sample by size and vintage of the investable private European infrastructure market, and include hundreds of firms over that period.

In this paper, the first using the EDHEC*infra* equity benchmarking database and technology, we focus on three questions:

1. How does a "broad market" index of private infrastructure equity investments perform relative to a public equity market reference index?
2. Is there a difference between the risk-adjusted performance of the three typical infrastructure business models (Blanc-Brude, 2014)–contracted, merchant, and regulated infrastructure–or between investing in "project finance" vehicles and "infrastructure corporates"?
3. How much diversification of investment-specific risk can be achieved in portfolios of private infrastructure equity investments?

The first two questions have been at the centre of the recent debates on the definition of an "infrastructure asset class," be it for asset-allocation or prudential purposes.

The third one is essential to better understanding how asset owners and managers can aim to access this asset class and not

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be limited to a few large, active bets (alpha), thus contradicting recent paradigm shifts in asset and risk management, including the twin objectives to focus on passive investing and remunerated risk factors (betas).

When developing this research, we also used two competing views of what defines infrastructure investment:

1. The first one equates infrastructure investment with "project finance" [5].
2. The second view, also expressed during recent prudential regulatory consultations, defines infrastructure investment more broadly and proposes to include so-called infrastructure corporates to the definition of qualifying infrastructure assets, effectively arguing that a number of firms–because they operate in industrial sectors corresponding to real-world infrastructure–constitute in themselves a unique asset class, with its own risk/reward profile.

5 - I.e., firms that are expected to operate within very strict constraints over the life of a single investment project, such as a toll road or a power plant.

In other words, it can be argued that the investment characteristics of "private infrastructure" are derived from the specific corporate governance structure found in limited-recourse project finance, or alternatively, that they primarily arise from the nature of the borrower's business (e.g., the provision of essential services, the low price elasticity of demand, etc).

With this research, we examine the extent to which these two approaches to defining infrastructure may overlap or not in terms of risk-adjusted financial performance.

We also examine the differences between the different "business models" found in infrastructure investment and how *merchant*, *contracted*, and *regulated* infrastructure firms contribute to broad market performance.

Arriving at a clear definition of the "infrastructure equity asset class" matters beyond academic research because it may, for example, imply a specific prudential treatment. The European Union insurance regulator highlighted this point in its June 2016 advice to the European Commission that "qualifying infrastructure" needs to be defined for the purposes of the Solvency-II directive (EIOPA, 2016).

Likewise, investors need to identify which unique characteristics found in private infrastructure equity–if any–are of interest to them and can help them meet their long-term investment objectives.

Answering the three questions highlighted above is a first step in the implementation of an ambitious research agenda at EDHEC*infra* to fully integrate private illiquid assets like infrastructure equity into long-term investment solutions.

The rest of this paper is structured as follows: Section 2 describes the definition of the investable universe, the selection of individual firms, and the processing of firm-level data.

# 1. Introduction

Section 3 summarises the methods used to compute the indices, from cash flow models to asset pricing to portfolio construction.

Section 4 presents and compares the results for six major private infrastructure equity indices: a broad market index, an infrastructure project index, an index of "infrastructure corporates," and infrastructure "merchant," "contracted," and "regulated" private equity indices.

Section 5 summarises and concludes.

# 2. Universe and Data

# 2. Universe and Data

In this section, we describe the approach taken to identify investable infrastructure firms and to create a representative sample to be included in a broad market private equity infrastructure index for Europe.

## 2.1 Investable Universe and Market Sample

### 2.1.1 Coverage

Research in finance on private or unlisted investment often suffers from multiple biases created by the various sources of data available. If private data is contributed solely by a limited group of asset managers and investors, it is likely to overweight the better, larger investments and very unlikely to represent the structure of the investable market in terms of country and sector distribution.

To avoid such biases, when selecting index constituents and collecting data, we take a bottom-up approach:

1. Given a region and its core countries, we first document the structure of the investable infrastructure sector in each national market. This includes documenting how investors might become the owners of either individual project companies or SPVs, or of firms that operate in a limited group of industrial sectors and focus narrowly on the provision of infrastructure-like services. These include ports, airports, firms engaged solely in energy distribution, water treatment and distribution or other activities typically understood to correspond to "infrastructure." The latter are selected only if the majority of their commercial activity is related to providing certain infrastructure services in a narrow sense;[6]
2. We identify which broad categories each identified firm belongs to (i.e., sector, type of corporate structure, and business model);
3. We then build a representative sample for the whole region in line with country, sector, corporate structure, and business model distribution of all investable infrastructure firms (an approach known a *stratified sampling*).

Thus, we avoid creating biases in the data collection by overweighting data made available by any one contributor.

All infrastructure firms included in the analysis are privately owned and operated, hence they are "investable" in the sense that they can be acquired or lent to during the period of interest.

Going back to the early-to-mid-90s depending on the country, we identify a population of 2,687 private infrastructure companies that has, at one point, been investable. Not all of these firms are investable today. Some projects have reached their maturity and disappeared. Some have been acquired and integrated within a larger firm–in which case they are dropped from the universe–and some have been terminated or gone bankrupt.

6 - Multi-utilities and infrastructure conglomerates are excluded.

# 2. Universe and Data

Among these firms, 2,301 are still alive in 2016, representing 790 billion euros of total asset book value. These firms are categorised by country, broad industrial sector groups, and "business models" following the nomenclature put forward in previous EDHEC publications (see for example Blanc-Brude, 2014).

Next, the private infrastructure equity universe we consider is built to be a representative subset of the investable infrastructure market in 14 European countries.

400 firms are selected to create an **index sample** representing around 50% of each national, industrial, and business model segment by size at any point in time. We also require that each firm has been operating for at least four years to be included in the index sample. In 2016, 372 firms are alive in the index sample. The indices later described in section 4 are built using this **market sample.**

Detailed information about the firms included in the market sample is then collected according to the template described in Blanc-Brude et al. (2016).

Figure 8 shows the proportion of the live investable European market covered by the index sample from 2000 to 2017. The number of live constituents in the index is indicated by the blue-gray dots, while the pink line indicates the share of total value in the investable universe tracked by the sample.

Figure 8 shows the evolution of the investable infrastructure population identified in Europe over the period. A decade and a half ago, fewer private investment opportunities existed in Europe, and they were, generally, larger companies such as regulated water and power utilities.

Since then, in the wake of the UK, European governments have embarked on a series of public-private-partnership programs that have greatly increased the number of investment opportunities but also considerably reduced their average size.

Even more recently, the development of renewable energy projects in the wind and solar sectors has also led to the creation of numerous but relatively small infrastructure firms.

As a result, our index sample includes 155 firms in 2000, representing 54.6% of the investable firm universe at the time by total book value. It peaks at 394 firms or 52.4% of the universe in 2012.

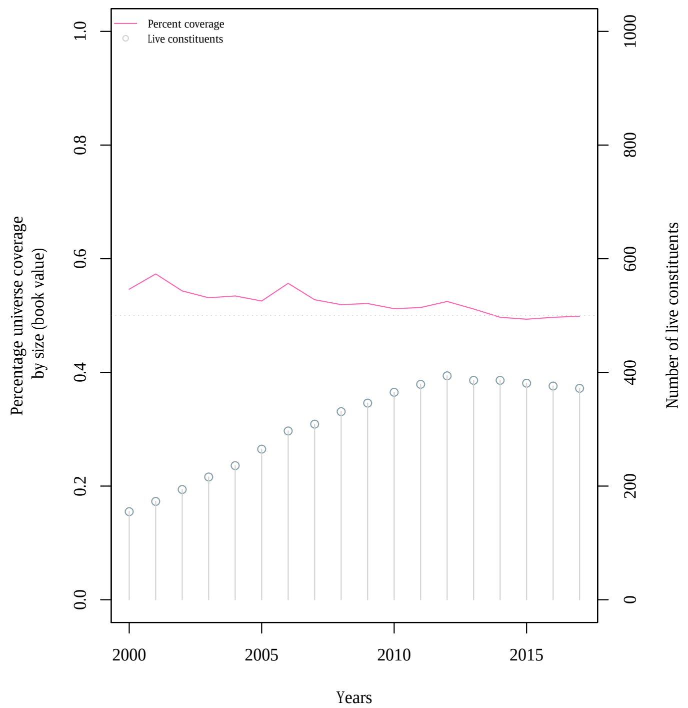
Today, partly as a result of multiple bankruptcies in the Spanish road sector since 2012, our index includes 372 live companies or 49.8% of the investable universe.

### 2.1.2 Private Infrastructure Universe Breakdown

A 2016 snapshot of the infrastructure equity market sample, broken down by number of firms is given in figures 9, 10, and 11

# 2. Universe and Data

Figure 8: Universe coverage of market sample




for country, sector, and corporate structure categories, respectively.

Similar breakdowns by market value are available for individual indices and are described in the appendix for the three indices discussed in section 4.

## 2.2 Data collection

### 2.2.1 Infrastructure Firm Data

Once the relevant firms are identified, in a second step, the relevant data is collected for a representative sample of the investable universe **for which the best data can be collected**.

Hence, the use of data contributed by private investors is maximised but without creating sampling biases. For all other individual firms in the sample, we collect the relevant data from a range of public and private sources, including audited financial accounts, freedom-of-information requests, commercial databases, etc.

Detailed financial information is collected for all firms in the market sample, from their incorporation date to year-end 2016 or their date of cessation of operations. The consistency and integrity of each firm's financials is ensured as well as the details of their financial structure through time, from the creation of the firm until today.

Following the EDHEC*infra* template, we collect data about each firm and each debt instrument identified as part of its capital

# 2. Universe and Data

Figure 9: Index sample country breakdown

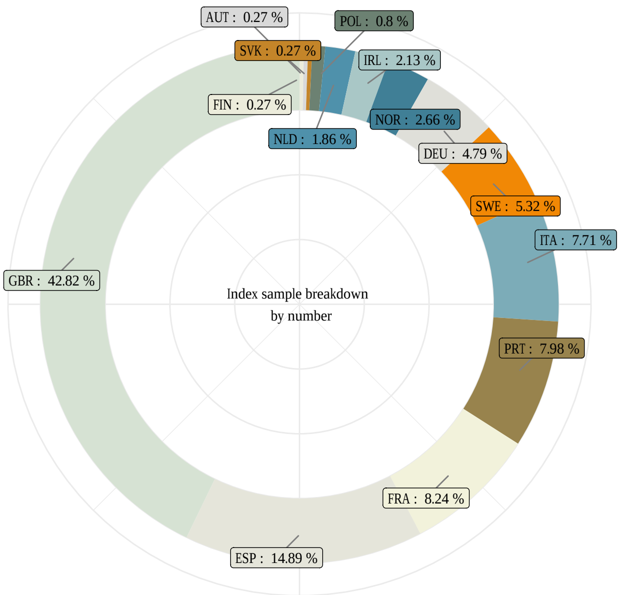
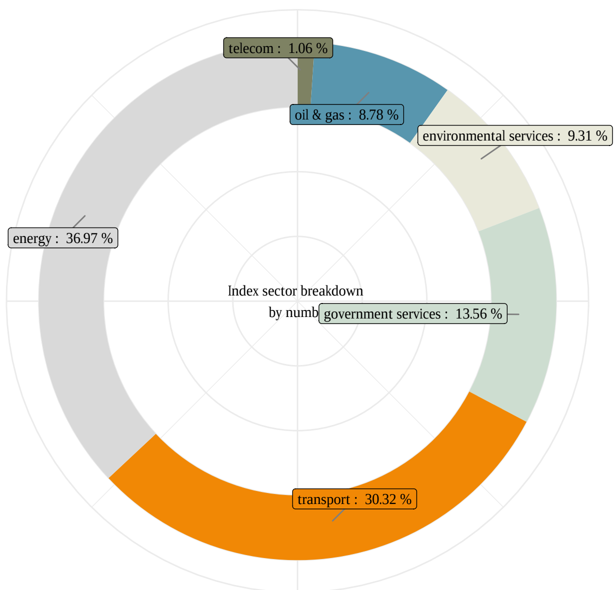
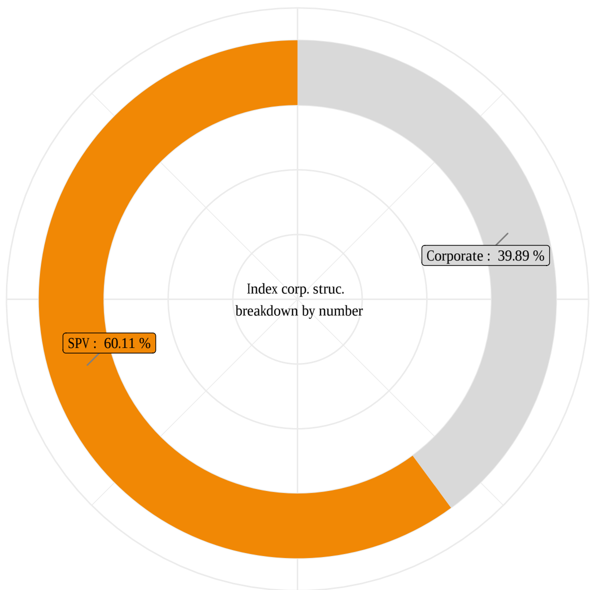



Figure 10: Index sample sector coverage breakdown



# 2. Universe and Data

Figure 11: Index sample corporate structure breakdown




structure. Firms are also the subject of a number of *events*,[7] firms and instruments also have individual *attributes*,[8] and they are also attached to *values* (see Blanc-Brude et al., 2016, for a detailed discussion).[9]

7 - E.g., incorporation, construction start and completion, operational phase start, defaults, refinancing and restructuring, prepayments, end of investment life, etc.

8 - E.g., for firms, business model, type of regulation, contracted or indexed nature of inputs and outputs, etc.; for instruments, seniority, currency, repayment profiles, interest rates, maturity date, etc.

9 - E.g., for firms, any items of balance sheet, P&L, or cash flow statement, forecast or realised; for instruments, realised and future interest and principal repayments.

Sources used include annual audited accounts filed with the relevant regulators in each country; contributed data from asset managers, asset owners, and lenders; freedom of information requests; and commercial and open-access databases of infrastructure projects and project finance and merger and acquisitions. The physical and spatial characteristics of each infrastructure are also collected and can be used to map the constituents of different subindices (not shown here).

This data is collected from multiple sources and aggregated, cross-referenced, analysed, and validated by a series of algorithms and a team of human analysts. Each firm's data is reviewed iteratively at five different levels of computer-based and human validation.

### 2.2.2 Market Benchmark Data

Market benchmark data used to estimate risk-free rates and market comparators is sourced from Datastream and ERI Scientific Beta, an EDHEC affiliate specialised in equity indices.

In the next section, we describe the methodologies used to model the cash flows of each firm and derive the term structure of discount factors required for the valuation of each firm in the index.

# 3. Methodology

# 3. Methodology

## 3.1 Overview

This section provides an overview of the technology used to derive the index results presented in the next section. More details can be obtained from individual EDHEC publications describing the theoretical background and technical development of each component of this methodology. These publications are referenced below.

Private infrastructure equity is seldom traded, and only a limited amount of market-price data is observable. Hence, the risk-adjusted performance of each firm in the index sample is derived by forecasting cash flows to each firm's owners (including any shareholder loans and other payouts other than dividends) and discounting them according to duration and volatility of future payouts and prevailing market conditions. A term structure of discount rates is thus inferred from observed market prices, including the initial value of the investment and comparable transactions taking place each year.

Once each firm's equity stake has been valued in each period, the derivation of the relevant risk-adjusted performance metrics at the asset level is straightforward.

Individual assets are then combined to represent the performance of a given portfolio or index.

To implement this approach, a number of building blocks are needed:

1. A model of the "free cash flow to equity" (FCFE) until the end of the investment life or the next 50 years, whichever is shorter, is implemented using information about the firm's revenues, capital, and operating costs, as well as its capital structure, debt service cover ratio, and future debt service;
2. The mean and variance of each firm's FCFE "retention rate" or RR (i.e., cash at bank / FCFE), is estimated in all realised periods, and a forecast of its mean and variance is made for the remainder of the investment's life. In other words, the firm's RR is treated as an unobservable stochastic process, the parameters of which we estimate over time;
3. The combination of the forecast of the mean and variance of FCFE and RR allows computation of a stream of expected equity payouts and conditional (future) payout volatility;
4. Firms are grouped by risk "clusters" or buckets, as a function of their payout volatility and time to investment end (a proxy of duration);
5. Within each "risk bucket," a term structure of discount factors is derived, reflecting the value of the investment relative to expected payouts and conditional payout volatility, duration, and any relevant and observable market prices (primary and secondary transactions) in each year in the same risk cluster;
6. Finally, after individual performance metrics have been obtained for each firm's senior debt, a return covariance matrix is estimated for each index,

# 3. Methodology

and individual assets are aggregated following preset inclusion and rebalancing rules.

## 3.2 Cash Flows

The first step in our asset-pricing methodology is to estimate future equity payouts and their risk (conditional volatility). Equity payouts are defined as any cash flows paid by the firm to its owners and include dividends but also shareholder loan servicing and any fee or other monies returned to shareholders.

A first approach consists of trying to model these payouts "directly." That is, given observable payouts, what is the stream of expected future payouts?

Unfortunately, observing equity and quasiequity payouts does not necessarily allow for very robust estimation of the payout process at the firm level. Private firms tend to have a more erratic dividend payout behaviour than listed firms, and their equity payouts can vary considerably in size and frequency.

This is certainly the case with the infrastructure firms in our sample. While some pay dividends regularly, other pay out in irregular and more unpredictable ways. A small subsample (less than 10%) has never paid out a dividend, some in more than ten years of operation.

Even these "zero payout" firms can be assumed to have a positive present value (otherwise investors would not hold them). They should not be excluded from our broad market infrastructure equity index, since they represent a certain pattern of equity payout found in the market.

We model each firm's future equity payouts indirectly and proceed in two steps:

1. We first estimate the parameters of the firm's free cash flow process (i.e., its FCFE). This first quantity can always be observed as long as a firm is operational, it must have a free cash flow (even if it is negative);
2. We then estimate the firm's FCFE retention rate, that is, its tendency to distribute FCFE in any given period. Likewise, this quantity is always observable and partly embodies the economic dynamic of the firm, including its ability and tendency to reinvest free cash, to keep it in various reserve accounts, or to distribute it to residual claimants.

The future free cash flow to equity of each firm is defined as

$$FCFE_t = CFADS_t - DS_t$$

where $DS_t$ is the senior debt service owned at time $t$ and $CFADS_t$ is the cash flow available for debt service (a.k.a. the free cash flow) at time $t$. This is obtained from private contributor data and computed using individual firms' audited accounts.

The FCFE retention rate (RR) is computed as

$$RR_t = \frac{\text{Cash at Bank}_t}{FCFE_t}$$

# 3. Methodology

where Cash at Bank$_t$ is all cash held at bank at the end of each period and $FCFE_t$ is the free cash flow to equity as defined above.

Hence, $RR_t$ measures the ability and tendency of each firm to retain free cash flow to equity instead of distributing it to shareholders. Particularly in infrastructure projects with a finite life, it can be expected to follow the firm's lifecycle and take the value of 0 in the last year.

Conversely, with "infrastructure corporates" $RR_t$ can be expected to follow different regimes depending on the firm's life and history, including the impact of any regulatory changes.

Thus, the equity payouts of each firm can simply be written:

$$Payout_t = FCFE_t \times (1 - RR_t)$$

Next, our approach requires modeling and forecasting the expected value and volatility of a firm's FCFE and RR at each point in its life.

Any observations of these two quantities are treated as realisations of an otherwise unobservable stochastic process, the true parameters of which can be "filtered out" from noisy observable data.

Next, we describe how the parameters of the $RR_t$ process are estimated using signal processing techniques.

### 3.2.1 RR State Estimation

In a first step, the mean $\mu$ and variance $\sigma^2$ parameters (or state) of the $RR_t$ process have to be inferred from observable data. Since between 4 and 20 years of realised values are available for each firm, it is not possible to derive a robust and unbiased estimation of cash flow dynamics at the firm level using standard or "frequentist" statistical techniques.

Instead, Bayesian techniques (Monte Carlo Markov Chain) are used to infer the true value of the mean and variance parameters of the $RR_t$ process in each period, based on an initial guess (or prior) and an autoregressive model expressing a firm's ability and tendency to pay dividends in any given year as a function of its ability and tendency to do so in the previous year and of the effect of various control variables (e.g., time-to-end, future debt service, behaviour of similar projects, etc.).

This "state-space" model can be represented by the following two equations:

$$x_t = f_t.x_{t-1} + \varepsilon_t \text{ (state equation)}$$

$$y_t = g_t.x_t + \eta_t \text{ (observation equation)}$$

where $x_t$ is the unobserved state of the system at time $t$, $y_t$ is the RR observation at time $t$, $f_t$ is the "evolution" function, and $g_t$ is the vector containing relevant control inputs. $\varepsilon_t$ and $\eta_t$ are two independent white noise sequences with mean zero and variance $\sigma^2$ and $\omega^2$ respectively, which are the unknown parameters.

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With each $RR_t$ observation, the true value of the mean and variance parameters of each firm's RR and their evolution in time is "learned"–just like a self-driving car continuously reassesses its coordinates in an $(x, y)$ plane, we continuously reassess the position of the RR process in the $(\mu, \sigma^2)$ plane.

Figures 12 and 13 illustrate this process for two example companies in the UK and Portugal.

In figure 12, the estimated true mean and volatility of the FCFE retention ratio process is shown as a trajectory in the mean / standard deviation plane, as estimated parameters evolve year after year based on observed data.

It should be noted that the level of estimated volatility of the FCFE retention rate can vary considerably from one firm to another, but it also tends to follow a trend.

Figure 13 shows the time $t$ value of the RR mean and variance is predicted at time $t-1$ and effectively tracks the realised RR value at time $t$ (here until 2015).

*$RR_t$ forecasting*

Once the parameters of the RR distribution of each firm have been derived for realised time periods, we use these estimates to derive a *forecast* of the mean and variance of the firm's RR until the end of the investment.

This is achieved by implementing Kalman filtering techniques with recursively computed "innovations" of the RR process as described in Wang and Blanc-Brude (2017) and illustrated in figure 13.

In view of the Markovian (autoregressive) nature of the state space model, the recursive formulae of the mean and variance of the firm's RR at a future time $t+k$, given the observed data up to time $t$, are derived using Bayesian methods: the $\mu_t$ and $\sigma_t^2$ at time $t$ act like an initial distribution (prior) of the future evolution of the model, which provides a summary of available data that is sufficient for predictive purposes.

Hence, the corresponding posterior distribution contains all the information about the future provided by the available data. As $k$ becomes larger, depending on the corporate structure and business model of the firm, uncertainty increases in the system, and the forecasts of the future true values of $\mu$ and $\sigma^2$, conditional on today's information, can become less precise, just like long-term prices are forecasted with less certainty by market forces processing all available data today.

Figure 13 shows that the $RR_t$ process forecast is influenced by several control variables, including the firm's lifecycle and the level of future senior debt repayments.

The estimation of the realised and future values of $FCFE_t = CFADS_t - DS_t$ uses a similar approach to the one above. It relies on the fact that $CFADS_t = DSCR_t \times DS_t$, where $DSCR_t$ is the firm's senior debt cover

# 3. Methodology

Figure 12: Estimated RR mean and variance trajectory in time

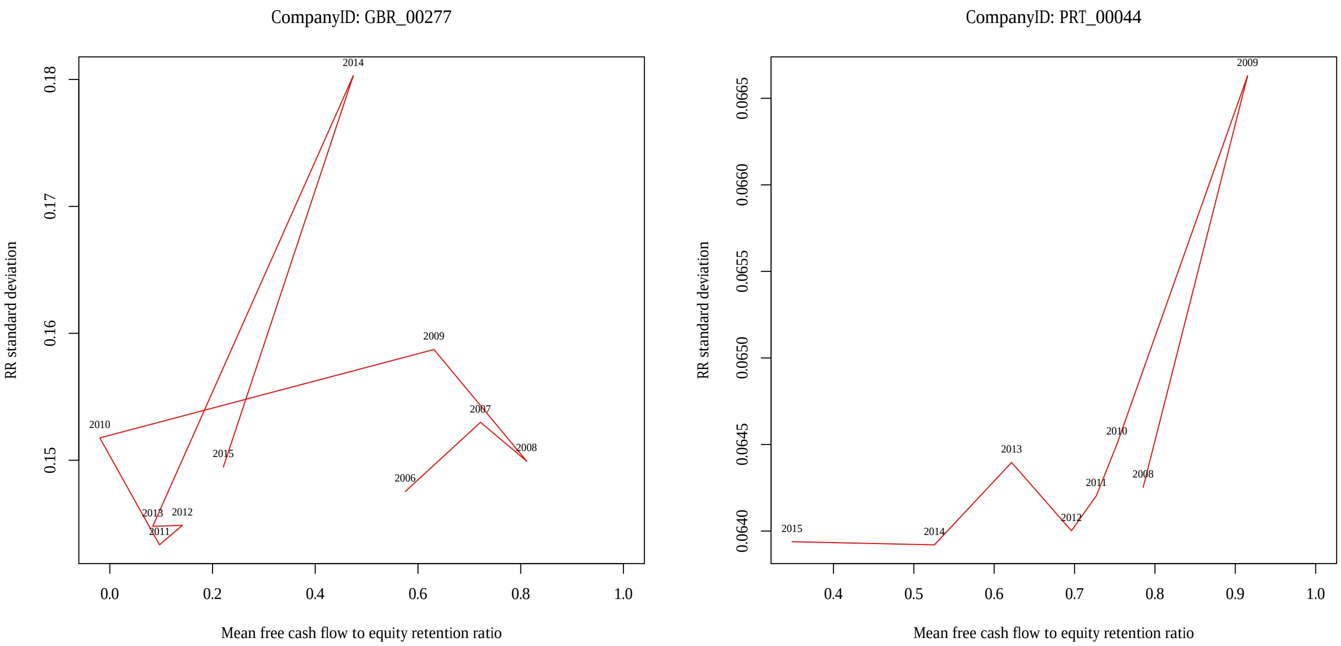
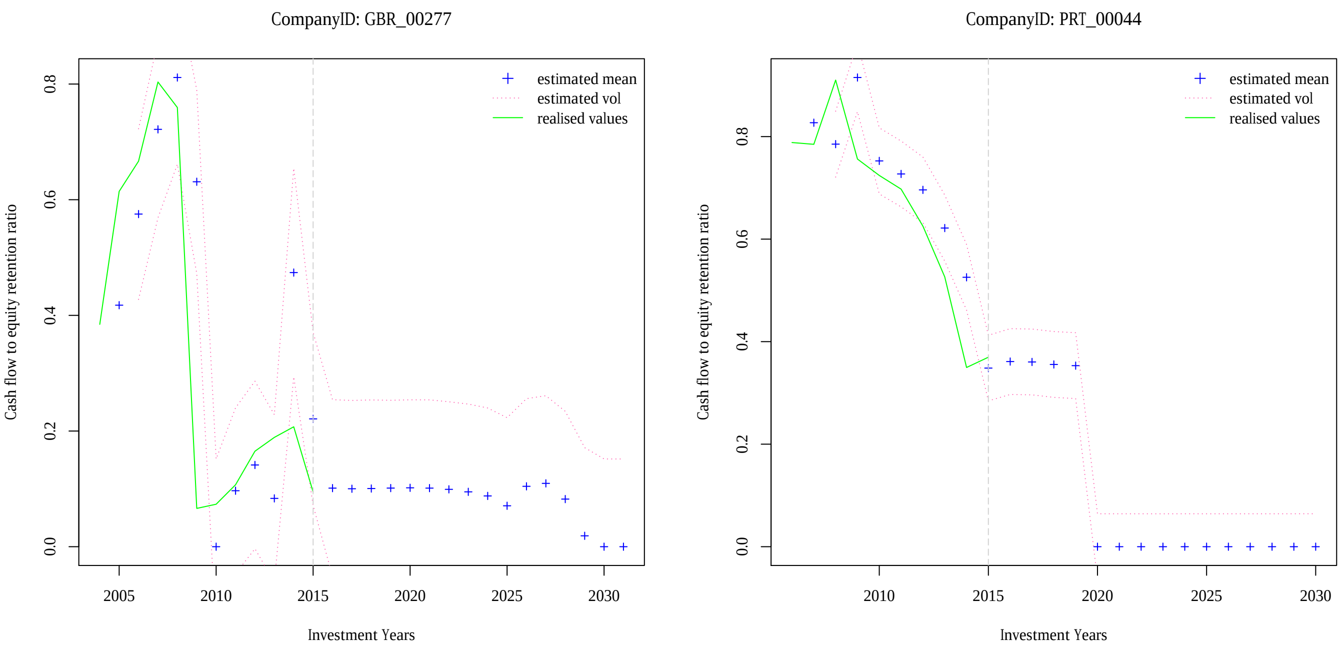



Figure 13: Estimated and forecast RR mean and variance in time



# 3. Methodology

ratio and $DS_t$ is its debt service. $DS_t$ is typically known, and $DSCR_t$ is a financial ratio that can be modeled as a stochastic process just like $RR_t$ (see Blanc-Brude et al., 2016, for a full version of the DSCR model we use).[10]

Hence, we can derive a forecast of future payouts to equity holders and their volatility at each point in the future, given the information available today.

## 3.3 Asset Pricing

### 3.3.1 Risk Buckets

Next, once the $RR_t$ mean and conditional volatility are known, each firm is assigned to a risk cluster or bucket in each year, as a function of its main risk characteristics. Hence, firms that have reasonably similar credit risk (as captured by the standard deviation of $RR_t$), duration (as proxied by time-to-maturity), and lifecycle stage (as proxied by the number of years since the firm's operations began) are assigned to the same risk bucket.

The rationale for this "bucketing" of individual firms is that firms with similar risk characteristics are assumed to represent the same combination of priced risk factors and carry–on average and at one point in time–the same risk premia.[11]

Hence, this grouping of firms into reasonably homogenous volatility and maturity or age groups is useful for two purposes:

1. Deriving discount rates that correspond to a persistent combination of priced risk factors;
2. Computing pair-wise return covariances within clusters using the cluster mean return as the expected return for all assets in the same bucket.

This approach improves on those previously put forward by Blanc-Brude and Hasan (2015) by which "families" of infrastructure firms, defined more loosely in terms of business model, were considered sufficiently homogeneous to capture well-defined combinations of priced risk factors. In practice, some merchant projects may behave more like contracted ones, and some contracted firms like regulated or merchant ones, etc.

The distinction between business models remains valid for the purpose of building subindices (see section 3.4), but hierarchical clustering allows the derivation of more robust pricing measures and covariance estimates.

Hierarchical clustering aims to group a set of objects in such a way that objects within each cluster are more similar to each other than to those in different clusters. It is a bottom-up approach by which, at each level, selected pairs of clusters are recursively merged into a single cluster, thus producing a new grouping at the next step (with one less cluster). The pair chosen for merging consists of the two groups with the smallest intergroup dissimilarity. The number of final

10 - In the few cases where firms have no senior debt or no more senior debt (hence no $DSCR_t$), then $FCFE = CFADS_t$ and the free cash flow process is modeled directly using a growth-trend model.

11 - Still, the heterogeneity of investor preferences with regards to this otherwise homogenous group of assets implies that there is a range of required risk premia applicable to each bucket (see Blanc-Brude and Hasan, 2015, for a detailed discussion of the role of investor preferences in illiquid markets).

# 3. Methodology

groups depends on the heterogeneity of the original data.

Figure 14 illustrates this process: firms from all three infrastructure business models (contracted, merchant, and regulated) can somewhat overlap in terms of RR variance, and for the purpose of asset pricing, much more homogenous risk groupings can be made using hierarchical clustering.

### 3.3.2 Discount Factors

In the context of estimating asset values for a market index, we implement an approach described in Blanc-Brude and Hasan (2015) by which a term structure of discount factors is derived for each future payout. This approach is consistent with the usual intertemporal capital-asset-pricing models, such as Brennan and Xia (2003), Parker and Julliard (2005), and Dittmar (2002), and can be applied to equity payouts.

In a first step, we use a no-arbitrage asset-pricing model (a generic factor model of asset returns) to write discount rates in terms of risk-free rate and a risk premium. Next, we estimate forward-looking risk-free rates and the price of risks to obtain a term structure of risk-adjusted discount rates.

A general factor model of asset returns can be written as:

$$\begin{aligned} r_{i,t+1} = r_{f,t+1} \\ &+ \sum_k \beta_{F_k,t+1|t} E_t \left( r_{F_k,t+1} - r_{f,t+1} \right) \\ &+ \varepsilon_{i,t+1} \end{aligned}$$

where $r_{i,t+1}$ is the return on $i^{th}$ asset, $r_{f,t+1}$ is the return on a risk-free asset, $\beta_{F_k,t+1|t}$ is the asset's exposure to $k^{th}$ risk factor, and $E_t \left( r_{F_k,t+1} - r_{f,t+1} \right)$ is the expected excess return on the $k^{th}$ risk factor. The above equation can be rearranged to write the factor model of asset returns thus:

$$r_{i,t+1} = r_{f,t+1} + \lambda_{i,t+1|t} \sigma_{i,t+1|t} + \varepsilon_{i,t+1}$$

with the excess return on any asset, $r_{i,t+1} - r_{f,t+1}$, written as the asset's forward-looking volatility, $\sigma_{i,t+1|t}$, times the forward-looking "'price of risk," $\lambda_{t+1|t}$, where the price of risk depends on the Sharpe ratio of the risk factor, $\frac{\left( r_{F,t+1|t} - r_{f,t+1} \right)}{\sigma_{F,t+1|t}}$, and the asset's correlation with that risk factor, $\rho_{t+1|t}$.

Thus, the risk-adjusted discount rate for a $\tau$-period ahead cash flow is written:

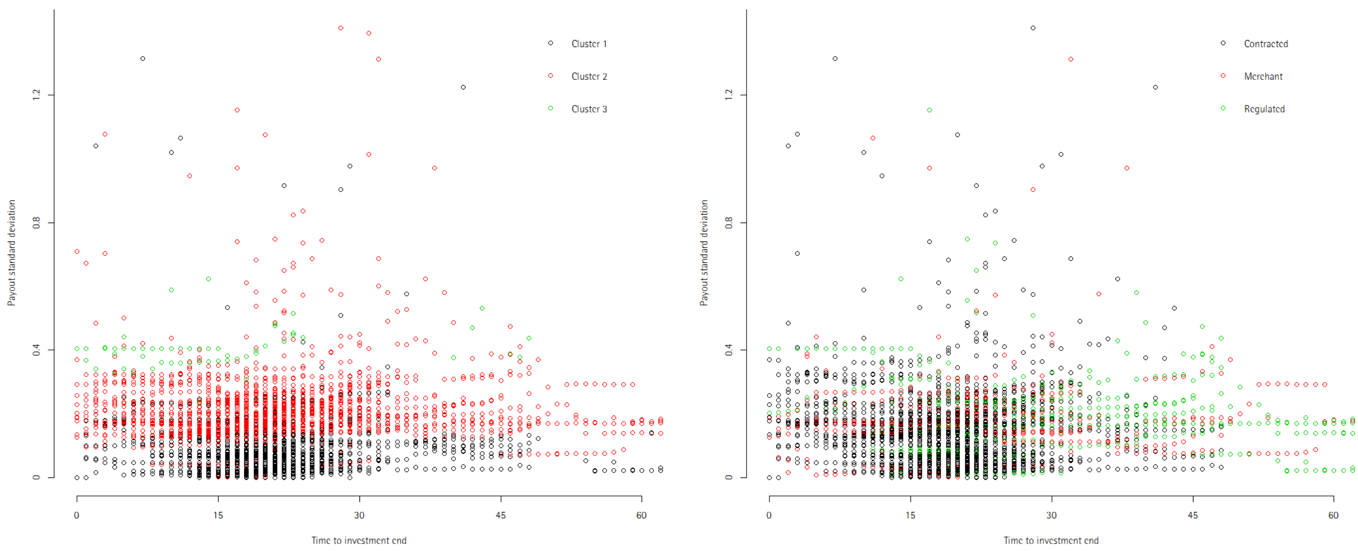
$$r_{i,t+\tau} = r_{f,t+\tau} + \lambda_{i,t+\tau|t} \sigma_{i,t+\tau|t} + \varepsilon_{i,t+\tau}$$

where $\sigma_{i,t+\tau|t}$ and $\lambda_{i,t+\tau|t}$ now denote a $\tau$-period ahead forecast of the asset's risk and the price of risk, respectively, as seen by the investor, from time $t$.

One advantage of writing the factor model in this form is that if volatility can be modeled directly–as is the case here–then the price of risk can be inferred from the prices of observed transactions.

That is, given a time-series of volatility estimates, $\sigma_{i,t}$, a time-series of $\lambda_{i,t}$ can be estimated such that the observable transaction prices match the prices implied by the asset-pricing model. This approach simplifies the task of having to model the expected returns and volatilities of priced

Figure 14: Hierarchical cluster and business model groupings of infrastructure borrowers in the RR variance and time-to-end plane




factors and the correlations of the asset with each priced factor.

Indeed, another important advantage of this approach is that it does not require identifying priced risk factors explicitly. As argued above, private infrastructure equity may be exposed to combinations of priced risk factors that we called risk clusters or buckets, and the price for all risk factors in any given cluster is summarised by $\lambda_{i,t}$, which can be estimated from observable prices, forecasted cash flows, and conditional payout volatility.

Since the only asset-specific term in the price of risk is the asset correlation with the factors, $\rho_{k,t}$, all assets with one risk cluster, with identical exposures to a given combination of priced risk factors, should earn identical mean returns.

Therisk buckets described in section 3.3.1 allow for such direct derivation of the price of risk for any homogenous grouping of firms.

Next, to empirically estimate the prices of risk of different risk exposures, we first estimate a term structure of relevant risk-free rates using standard term structure methodologies, such as Ang et al. (2006). Then, we collect observable risk premia information for senior loans and bonds (i.e., available market price data). These spreads can then be expressed in terms of risk premia as:

$$spread_{i,t} = \sum_k \lambda_{k,t}\sigma_{k,t} + \varepsilon_{i,t}$$

where $spread_{i,t}$ is the observed premium on the $i^{th}$ loan, $\lambda_{k,t}$ is the price of $k^{th}$ risk exposure, and $\sigma_{k,t}$ is the size of the $k^{th}$ exposure. The different risk exposures that we consider include cash flow risk,

# 3. Methodology

as measured by the "cluster" to which the project belongs based on a cluster approach described in section 3.3.1; interest rate risk, as measured by the effective duration of the instrument; country risk, as proxied by a country dummy; and market conditions at the time of the origination of the loan, as proxied by the calendar year in which loans are originated.

The prices of risk are estimated by minimising errors between observed spreads and model-implied spreads, so that:

$$\min_{\lambda_{k,t}} \left( spread_{i,t} - \sum_k \lambda_{k,t} \sigma_{k,t} \right)$$

This allows estimation of the extent to which different risk exposures are priced. Performing this procedure year by year using instruments originated in each year, allows inference of how risk premia evolve over time. The time-series of estimated risk premia is then used to compute a time-series of spreads for each project in the same risk bucket.

In other words, the risk premia estimated using instruments originated in a given year are used to recompute current spreads for all live instruments, combining information about the current risk profile of each instrument (the latest iteration of the retention rate state and forecasting models) and prevailing market conditions.

This is as close as we can get to an actual mark-to-market measure of private infrastructure investments.

Hence, we can value each instrument in each year–including those years where the market price for individual instruments could not be observed for lack of secondary market transactions–thus overcoming the main data limitation faced in measuring the performance of highly illiquid private infrastructure projects over time.

A more detailed presentation of the discount factor term structure model and estimation techniques can be found in Hasan and Blanc-Brude (2017).

## 3.4 Portfolio Construction

Thus, a combination of cash flow, clustering, and asset-pricing models allows estimation of the full range of performance metrics required for investment benchmarking at the asset level: single-period rates of return, volatility of returns, Sharpe ratio, value-at-risk, duration, etc.

### 3.4.1 Covariance

To derive performance measures at the portfolio level, it is necessary to estimate the covariance of returns (i.e., the variance-covariance matrix) to take into account the effect of portfolio diversification.

Portfolio returns and risk are written in the usual manner:

$$R_P = w' R$$

$$\sigma_P^2 = var(w' R) = w' \Sigma w$$

with $R$ a vector of constituent returns, $w$ a vector of portfolio weights (adding up

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to unity), and $\Sigma$ the variance-covariance matrix of the portfolio returns.

When estimating $\Sigma$, the main challenge is always dimensionality. That is, estimating the covariance matrix of a portfolio made of a large number of assets is subject to a lot of noise or the "curse of dimensionality" (Amenc et al., 2010), where each pairwise covariance results in some estimation error and the multiplication of these errors with each other will soon undermine the estimation of portfolio risk as a whole.

One approach is to shrink the dimensionality of the problem by identifying a certain number of common factors driving project returns and to estimate the covariance matrix of factor returns instead.

In our case, the ultimate factor exposures of private infrastructure investments are unknown *ex ante*. Indeed, they are what we set out to discover. Hence, our approach to group assets by risk buckets (defined as statistical clusters of volatility and duration) aims to capture persistent but unknown combinations of priced risk factors.

Once covariance is known within each cluster, the covariance matrix can be written as the combination of intercluster and intracluster covariances and estimated in any given year for the main index or any subindex of private infrastructure equity.

Thus, consider assets $x^m$ and $y^n$ from risk clusters or buckets $m$ and $n$, respectively. The relevant covariance between the two assets is written:

$$cov(x^m, y^n) = \begin{cases} cov(x, y) \text{ if } m = n \\ cov(m, n) \text{ if } m \neq n \end{cases}$$

Hence, once the covariance of returns relative to the mean return has been estimated within each cluster and the covariance between clusters is also known–which has largely reduced the dimensionality problem in our case–the covariance component of any index or subindex constituent is readily known and the relevant index covariance matrix can be derived.

### 3.4.2 Portfolio Rules

Portfolio construction methodology consists of two elements: asset selection and weighting-scheme design.

Asset selection is done in the context of our effort to document a representative broad market index.

Hence, the selection of constituents and their rebalancing is largely driven by considerations of sampling and–to some extent–data availability and data quality.

We use two different weighting schemes: value weights and equal weights.

Value weighting is a standard way to proxy the "market," but it overweights the largest firm or firms and increases portfolio concentration. This could be a particular concern in the case of broad market infrastructure indices, since very large firms and issuers (utilities) are found side by side with relatively small project finance SPVs, the

# 3. Methodology

impact of which on the index is dwarfed by the largest firms.

Equal weighting thus represents a simple yet intuitive way to consider the contribution of all index constituents by maximising the "effective number of bets' and, arguably, providing a more representative view on the performance of private infrastructure equity.

In the context of traditional and liquid fixed-income and equity indices, index weighting schemes are associated with rebalancing decisions requiring buying and selling. In the case of highly illiquid private infrastructure investments, such rebalancing decisions are not possible. In practice, a direct investor or manager in private infrastructure equity cannot easily or speedily adjust their ownership of any given firm.

Here, on a value-weight basis, each exposure is considered to represent the whole stock of the firm. On an equal-weight basis, the size of the exposure is simply ignored. Hence, the indices we produce are **buy-and-hold portfolios** of private infrastructure equity.

In this sense, rebalancing only happens at the issuer-selection stage, that is, when building a representative portfolio of the identified investable universe. At each rebalancing , this sample has to be reassessed, because the underlying population and/or the index sample have changed. For example, certain instruments reach the end of their life or a limit set by an index-inclusion rule in terms of size and remaining maturity.[12]

The only inclusion rule is to pass a minimum size threshold of 1 million euros.

12 - Index constituents' weights are computed in a reference currency (here euros), irrespective of the choice of the reporting currency of the index.

# 4. Results

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The data and methodologies described in sections 2 and 3 allow the creation of indices focusing on specific geographies, sectors, business models, and corporate structures.

There are 192 such indices of European infrastructure private equity available on the EDHEC*infra* website, in three investment currencies and on a "fully hedged" basis. [13].

13 - I.e., ignoring the impact of exchange rate movements on portfolios that can include multiple instrument-level currencies.

In this section, we compare results for the six main indices of the pan-European private infrastructure equity market (14 countries): a broad market index, an infrastructure project index, and an index of "infrastructure corporates," and the three indices focusing on the main infrastructure business models: "merchant," "contracted," and "regulated."

Since we are interested in a pure infrastructure effect and less in the point of view of a USD or EUR investor, in what follows we only report the performance of "fully hedged" indices (i.e., assuming full currency hedging and only taking the local currency returns into account).

We also compare equally weighted and value-weighted portfolios to touch on the topic of portfolio diversification, a nontrivial question in the case of highly illiquid and bulky infrastructure investments.

Next, we review the composition and concentration levels of each of the six indices (4.1), their risk-adjusted performance (4.2), and extreme risk metrics (4.3).

## 4.1 Index Composition

The six key indices we examine for the 2000-2016 period are:

1. A **broad market infrastructure index**, covering 14 European countries and six industrial sector groups, includes 330 "live" firms in 2016, with a capitalisation of EUR293.5bn. Over the period, 398 firms have been included in the index;
2. A **private infrastructure project equity index** for the same geography including 235 live firms in 2016 for a capitalisation of EUR68bn (257 firms over the period);
3. An **infrastructure corporate equity index** with a EUR225.5bn capitalisation in 2016 for 95 live firms (103 firms over the period);
4. A **contracted infrastructure equity index** with 195 live constituents in 2016 or EUR47.2bn of capitalisation in 2016 (204 firms over the period);
5. A **Merchant infrastructure equity index** including 70 live firms and a total capitalisation of EUR75.2bn (86 firms over the period);
6. A **regulated infrastructure equity index** with 65 live 2016 constituents and representing EUR171bn of capitalisation (70 firms over the period).

New constituents enter the index when they become investable. Over time, some index constituents are removed from the "live" index because they have reached a minimum size threshold, go bankrupt and are liquidated, or are acquired by another firm following a bankruptcy.

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Figure 15: EDHEC*infra* **broad market** infrastructure equity index, 2016 **country** breakdown by market value

(a) value-weighted | (b) equally weighted

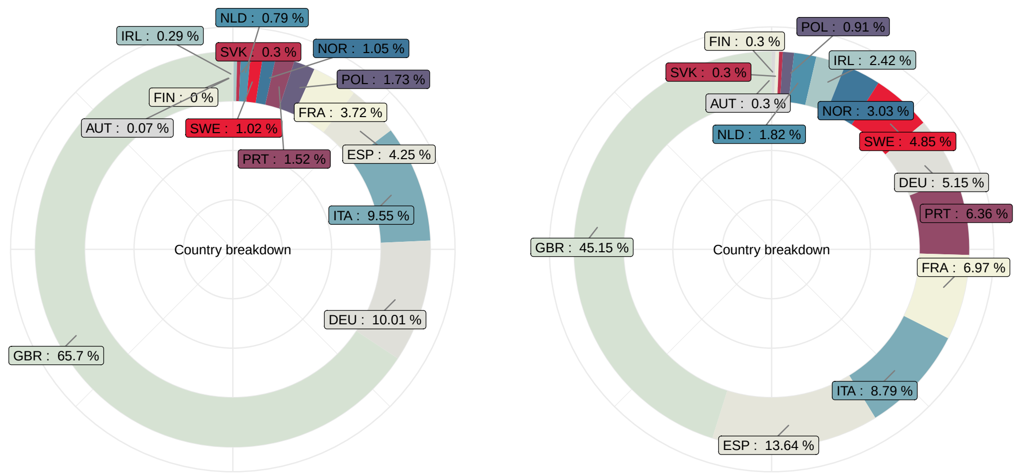


Figure 16: EDHEC*infra* **broad market** infrastructure equity index, 2016 **sector** breakdown by market value

(a) value-weighted | (b) equally weighted

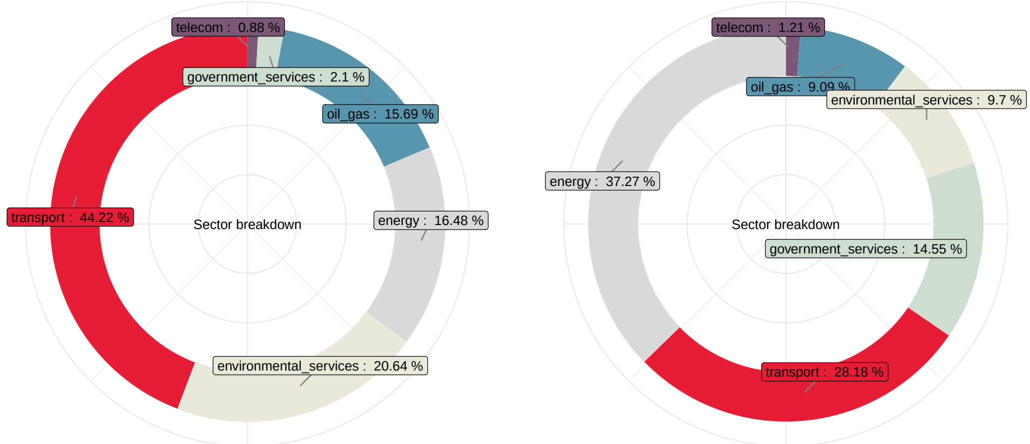

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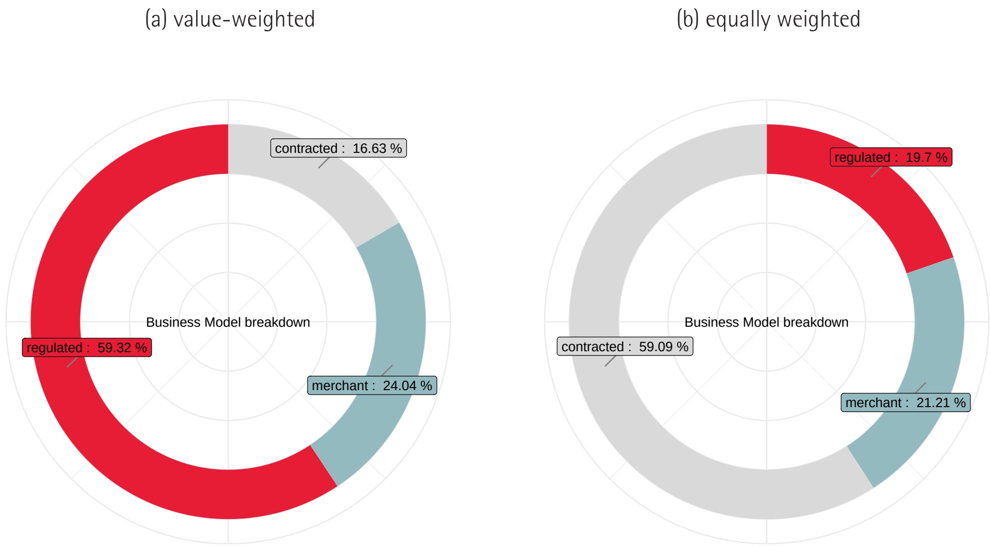
Figure 17: EDHEC*infra* **broad market** infrastructure equity index, 2016 **business model** breakdown by market value




### 4.1.1 Categories of Constituents

As before, each set of index constituents can be broken down by infrastructure business model, currency, country of origin, industrial sector, or corporate structure.

Figures 15, 16 and 17 show the composition of the broad market infrastructure equity index by country, sector, and business model, on a value-weighted and equally weighted basis.

Similar figures are available in the appendix (section **??**) for the infrastructure projects and infrastructure corporates indices, as well as for the contracted, merchant and regulated indices.

A value-weighted infrastructure index tends to privilege larger types of infrastructure firms, including utilities, ports, and airports. As a result, the broad market index includes a significant share of regulated and merchant firms with a large transport component.

In terms of geography, value weighting also tends to increase the share of countries which have implemented large-scale utility and transport-sector privatisation programs, typically going back to the mid-1980s.

Conversely, an equally weighted index sees the share of contracted infrastructure increase considerably, along with the energy and government services sectors: much smaller public-private partnerships (PPPs) and renewable energy projects are given a greater share of the index.

As a result, countries that have more recently implemented PPP procurement programs and encouraged the development of renewable energy have a greater share of any equally weighted index. In particular,

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the weight of the UK and regulated assets are considerably greater in value-weighted indices.

Thus, we note that size differences between infrastructure sectors introduce country and business model biases between indices with different weighting schemes.

Hence, the weighting scheme of the index can also imply different levels of correlation with the rest of the economy or other asset classes.

The other subindices focusing solely on infrastructure projects or corporates exhibit similar but less dramatic business model, country, and sector biases as a function of their weighting scheme, as can be seen in the figures in the Appendix.

Business model-based indices exhibit similar biases (e.g., on a value-weighted basis, European merchant assets are dominated by transport projects (toll roads)).

Next, we examine the degree of concentration of each index.

### 4.1.2 Concentration

Our private infrastructure equity indices represent theoretical "buy-and-hold" strategies: value-weighting simply means holding all the live constituents at time *t* weighted by their market value, while equal weighting simply means assuming equal shares for each borrower in the index at all times.

The absence of liquidity in the private infrastructure equity market and the presence of high transaction costs would make these two strategies hard to replicate in practice.

Instead, these are two ideal-type portfolio weighting schemes, aiming to represent the broad market from two significant and relatively intuitive perspectives.

Tables 3 and 4 compare the number of live index constituents in 2016 (number of eligible constituents) with the number of "effective constituents" or "effective number of bets,"[14] explaining most of the performance of the index due to their larger weights.

They also show the cumulative percentage of constituents necessary to reach 25%, 50%, etc. of the index total capitalisation.

In each table, panel A describes the concentration level of value-weighted indices in comparison with the public equity market reference index.

Clearly the value-weighted infrastructure indices are highly concentrated, even relative to the cap-weighted stock market reference index, which is not known for its focus on diversification benefits.

Only 6% of constituents suffice to represent half of the value-weighted index capitalisation. In the case of infrastructure corporates, 15 effective bets can explain most of the performance.

14 - A measure of portfolio concentration equal to the inverse of the Herfindahl-Hirschman index, that is, the sum of squared weights (see Meucci et al., 2013).

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Table 3: Weight profiles: broad market, project, and corporate infrastructure indices, Europe(14)

A) Value-weighted indices

| Metrics | Brd Mkt Infra (VW) | Infra Projects (VW) | Corp. Infra (VW) | Pub. Eq. Ref. |
|---|---|---|---|---|
| Effective Number of Constituents | 25 | 54 | 15 | 286 |
| Number of Eligible Constituents | 330 | 235 | 95 | 500 |
| Pct Constituents to 90pct Cap | 25 | 37 | 34 | 90 |
| Pct Constituents to 75pct Cap | 12 | 20 | 17 | 74 |
| Pct Constituents to 50pct Cap | 3 | 8 | 6 | 50 |
| Pct Constituents to 25pct Cap | 1 | 3 | 1 | 24 |

B) Equally weighted indices

| Metrics | Brd Mkt Infra (EW) | Infra Projects (EW) | Corp. Infra (EW) | Pub. Eq. Ref. |
|---|---|---|---|---|
| Effective Number of Constituents | 330 | 235 | 95 | 472 |
| Number of Eligible Constituents | 330 | 235 | 95 | 500 |
| Pct Constituents to 90pct Cap | 90 | 90 | 89 | 89 |
| Pct Constituents to 75pct Cap | 75 | 75 | 75 | 75 |
| Pct Constituents to 50pct Cap | 50 | 50 | 49 | 49 |
| Pct Constituents to 25pct Cap | 25 | 25 | 24 | 24 |

Table 4: Weight profiles: contracted, merchant, and regulated infrastructure indices, Europe(14)

A) Value-weighted indices

| Metrics | Regu. Infra (VW) | Cont. Infra (VW) | Merc. Infra (VW) | Pub. Eq. Ref. |
|---|---|---|---|---|
| Effective Number of Constituents | 11 | 45 | 9 | 286 |
| Number of Eligible Constituents | 65 | 195 | 70 | 500 |
| Pct Constituents to 90pct Cap | 34 | 38 | 31 | 90 |
| Pct Constituents to 75pct Cap | 18 | 21 | 19 | 74 |
| Pct Constituents to 50pct Cap | 8 | 8 | 6 | 50 |
| Pct Constituents to 25pct Cap | 0 | 3 | 0 | 24 |

B) Equally weighted indices

| Metrics | Regu. Infra (EW) | Cont. Infra (EW) | Merc. Infra (EW) | Pub. Eq. Ref. |
|---|---|---|---|---|
| Effective Number of Constituents | 65 | 195 | 70 | 472 |
| Number of Eligible Constituents | 65 | 195 | 70 | 500 |
| Pct Constituents to 90pct Cap | 89 | 90 | 89 | 89 |
| Pct Constituents to 75pct Cap | 74 | 75 | 74 | 75 |
| Pct Constituents to 50pct Cap | 49 | 50 | 49 | 49 |
| Pct Constituents to 25pct Cap | 25 | 25 | 24 | 24 |

In comparison, our equally weighted infrastructure indices have concentration profiles on par with the public equity market reference index, as shown in panel B of each table.

Next, we examine the performance of each index relative to the public equity market reference index.

## 4.2 Risk-Adjusted Performance

Table 5 shows key performance metrics for three of our indices (broad market, infrastructure projects, and infrastructure corporates) compared with the Scientific Beta developed Europe cap-weighted index reference, on a value-weighted basis. Table 6 shows similar results for the same indices using equal weights and compared to the Scientific Beta developed Europe maximum deconcentration index.

# 4. Results

Table 5: Private infrastructure equity key metrics, broad market, projects and infrastructure corporates, Europe(14), fully hedged, **value-weighted**

**A) Broad market**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 10.17% | 10.36% | 11.02% | 11.88% | 11.19% |
| Volatility | 9.06% | 8.59% | 8.67% | 9.19% | 10.64% |
| Sharpe Ratio | 1.33 | 1.39 | 1.42 | 1.33 | 1.1 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**B) Infrastructure projects**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 11.65% | 12.39% | 13.2% | 13.8% | 12.78% |
| Volatility | 5.14% | 5.18% | 5.27% | 5.34% | 6.6% |
| Sharpe Ratio | 2.63 | 2.69 | 2.76 | 2.65 | 2.1 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**C) Infrastructure corporates**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 9.69% | 9.72% | 10.37% | 11.32% | 10.78% |
| Volatility | 11.48% | 10.78% | 10.77% | 11.37% | 12.75% |
| Sharpe Ratio | 1 | 1.05 | 1.09 | 1.03 | 0.87 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**D) Public equity market index reference**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 2.62% | 6.73% | 11.96% | 5.72% | 9.59% |
| Volatility | 11.84% | 13.19% | 11.98% | 15.19% | 14.08% |
| Sharpe Ratio | 0.38 | 0.63 | 1.11 | 0.41 | 0.68 |
| Max Drawdown | 0% | 0% | 0% | 42.5% | 42.5% |

*Returns are time-weighted. Volatility is the standard deviation of returns. The Sharpe ratio is equal to excess returns divided by return volatility. In some years, the risk-free rate used to compute excess returns can be negative. Maximum drawdown is the maximum peak to trough in value over the reference period. The public equity index reference is the Scientific Beta developed Europe cap-weighted index (http://www.scientificbeta.com/#/index/WDX-xxxx-wCx). All public market reference metrics are computed using raw data and the same methodologies used for the infrastructure indices.*

Finally, tables 7 and 8 show the equivalent statistics for the contracted, merchant, and regulated private infrastructure equity indices, on a value- and equally weighted basis, respectively.

### 4.2.1 Broad Market Index

*Value-weighted index*

On a value-weighted basis, broad market private infrastructure equity (panel A1) outperforms the public equity market reference index in Europe (panel D) by a substantial margin at most of the reported investment horizons except at the 5-year horizon: outperformance is approximately to 170 bps historically, 600 bps at the 10-year horizon, and approximately -100 bps at the 5-year horizon.

We note, however, that the returns of the broad market infrastructure index are more consistent at different horizons, between 10 and 12% annualised.

Index return volatility (the combination of weighted individual asset returns with the covariance matrix of asset returns) is notably lower in the case of the infrastructure index, at around 9-10%, against the public equity index, which exhibits a return volatility between 11 and 15%.

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Table 6: Private infrastructure equity key metrics, broad market, projects and infrastructure corporates, Europe(14), fully hedged, **equally weighted**

**A) Broad market**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 12.52% | 13.28% | 13.96% | 14.48% | 13.56% |
| Volatility | 4.23% | 4.23% | 4.26% | 4.32% | 4.7% |
| Sharpe Ratio | 3.39 | 3.51 | 3.6 | 3.47 | 2.96 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**B) Infrastructure projects**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 13.55% | 14.42% | 15.09% | 15.47% | 14.45% |
| Volatility | 4.15% | 4.17% | 4.2% | 4.29% | 4.71% |
| Sharpe Ratio | 3.71 | 3.84 | 3.92 | 3.73 | 3.16 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**C) Infrastructure corporates**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 9.99% | 10.44% | 11.15% | 12.13% | 11.65% |
| Volatility | 6.42% | 6.38% | 6.37% | 6.32% | 7.06% |
| Sharpe Ratio | 1.84 | 1.88 | 1.97 | 1.99 | 1.7 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**D) Public equity market index reference**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 2.66% | 8.21% | 14.41% | 7.36% | 12.29% |
| Volatility | 13.25% | 13.27% | 12.39% | 16.71% | 15.5% |
| Sharpe Ratio | 0.34 | 0.74 | 1.27 | 0.47 | 0.79 |
| Max Drawdown | 0% | 0% | 0% | 47.82% | 47.82% |

*Returns are time-weighted. Volatility is the standard deviation of returns. The Sharpe ratio is equal to excess returns divided by return volatility. In some years, the risk-free rate used to compute excess returns can be negative. Maximum drawdown is the maximum peak to trough in value over the reference period. The corporate debt index reference is the Scientific Beta developed Europe maximum deconcentration (equally weighted) index (http://www.scientificbeta.com/#/index/WDX-xxxx-xDx). All public market reference metrics are computed using raw data and the same methodologies used for the infrastructure indices.*

As a result, the risk-adjusted measure or Sharpe ratio of the private infrastructure index is also higher, at a level of 1.1-1.3, against the more common level of 0.4-0.6 for the public equity index.

The annual maximum drawdown of the value-weighted, broad market infrastructure index is zero, whereas the public equity index has a historical maximum drawdown of 42.5%. The absence of extreme risk in the infrastructure index is confirmed when we look at annual returns and value-at-risk metrics below, which may also seem surprising.

Numerous infrastructure investors can testify to have experienced negative returns in particularly bad years, especially after the global financial crisis of 2008.

In fact, we record significant losses for a number of firms present in the index as well as higher return volatility in some years.

The absence of drawdown is explained by the nature of the investments: while some infrastructure projects are affected by external shocks and cyclical effects, many are not. At the index level, the negative performance of certain projects or firms is

# 4. Results

Table 7: Private infrastructure equity key metrics, contracted, merchant, and regulated infrastructure, Europe(14), fully hedged, **value-weighted**

**A) Contracted**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 11.32% | 11.88% | 12.56% | 13.7% | 12.94% |
| Volatility | 6.26% | 6.14% | 6.29% | 6.48% | 8.58% |
| Sharpe Ratio | 2.1 | 2.19 | 2.21 | 2.16 | 1.7 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**B) Merchant**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 13.02% | 14.06% | 14.67% | 14.85% | 13.34% |
| Volatility | 7.68% | 7.87% | 8.14% | 8.79% | 11.03% |
| Sharpe Ratio | 1.94 | 1.98 | 1.97 | 1.76 | 1.34 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**C) Regulated**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 8.68% | 8.53% | 9.27% | 10.37% | 10.09% |
| Volatility | 14.04% | 13.05% | 12.99% | 13.56% | 14.98% |
| Sharpe Ratio | 0.75 | 0.77 | 0.82 | 0.79 | 0.68 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**D) Public equity market index reference**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 2.62% | 6.73% | 11.96% | 5.72% | 9.59% |
| Volatility | 11.84% | 13.19% | 11.98% | 15.19% | 14.08% |
| Sharpe Ratio | 0.38 | 0.63 | 1.11 | 0.41 | 0.68 |
| Max Drawdown | 0% | 0% | 0% | 42.5% | 42.5% |

*Returns are time-weighted. Volatility is the standard deviation of returns. The Sharpe ratio is equal to excess returns divided by return volatility. In some years, the risk-free rate used to compute excess returns can be negative. Maximum drawdown is the maximum peak to trough in value over the reference period. The public equity index reference is the Scientific Beta developed Europe cap-weighted index (http://www.scientificbeta.com/#/index/WDX-xxxx-wCx). All public market reference metrics are computed using raw data and the same methodologies used for the infrastructure indices.*

diversified away. We return to this point in more detail below when we discuss the role of portfolio diversification.

Annual performance metrics for the value-weighted broad market infrastructure index are shown in figure 18a. Again, the infrastructure index exhibits more constant returns and no drawdown in bad years like 2008 or 2011, when it significantly outperforms the public equity reference index, but it has otherwise lower performance than equities except for the past three years.

Finally, figure 19a shows the cumulative performance of the broad market infrastructure index on a value-weighted basis. Again, equal weighting clearly increase overall performance over the 17-year period under consideration.

*Equally weighted index*

Next, we look at the equally weighted results. As discussed above, a value-weighted index of infrastructure assets can be relatively highly concentrated, even compared to the value-weighted reference index used here, due to the relatively large size of some of its constituents.

The equally weighted broad market infrastructure debt index (table 6) provides a

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Table 8: Private infrastructure equity key metrics, contracted, merchant, and regulated infrastructure, Europe(14), fully hedged, **equally weighted**

**A) Contracted**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 13.34% | 14.24% | 14.93% | 15.54% | 14.51% |
| Volatility | 4.08% | 4.11% | 4.16% | 4.29% | 4.86% |
| Sharpe Ratio | 3.72 | 3.84 | 3.92 | 3.74 | 3.12 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**B) Merchant**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 11.86% | 12.5% | 13.07% | 13.54% | 12.81% |
| Volatility | 6.85% | 6.84% | 6.75% | 6.5% | 7.08% |
| Sharpe Ratio | 2 | 2.05 | 2.13 | 2.15 | 1.85 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**C) Regulated**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 10.79% | 11.32% | 12.06% | 12.44% | 11.91% |
| Volatility | 7.11% | 6.96% | 7% | 7.21% | 8.27% |
| Sharpe Ratio | 1.78 | 1.85 | 1.92 | 1.79 | 1.5 |
| Max Drawdown | 0% | 0% | 0% | 0% | 0% |

**D) Public equity market index reference**

| | 1-year | 3-year | 5-year | 10-year | Hist |
|---|---|---|---|---|---|
| Return | 2.66% | 8.21% | 14.41% | 7.36% | 12.29% |
| Volatility | 13.25% | 13.27% | 12.39% | 16.71% | 15.5% |
| Sharpe Ratio | 0.34 | 0.74 | 1.27 | 0.47 | 0.79 |
| Max Drawdown | 0% | 0% | 0% | 47.82% | 47.82% |

*Returns are time-weighted. Volatility is the standard deviation of returns. The Sharpe ratio is equal to excess returns divided by return volatility. In some years, the risk-free rate used to compute excess returns can be negative. Maximum drawdown is the maximum peak to trough in value over the reference period. The corporate debt index reference is the Scientific Beta developed Europe maximum deconcentration (equally weighted) index (http://www.scientificbeta.com/#/index/WDX-xxxx-xDx). All public market reference metrics are computed using raw data and the same methodologies used for the infrastructure indices.*

different perspective: the public equity market reference index performs better than its value-weighted equivalent both in terms of time-weighted returns and Sharpe ratio, which is a standard result; the private infrastructure equity index sees its performance increased, but most importantly, its risk measure is considerably reduced to around 4.5%.

Using an equal-weight scheme has a very different effect in the public reference index and the private infrastructure index. In the case of public equities, equal weights have the effect of boosting performance because small cap stocks tend to have higher returns. The risk measure however is also higher, and the Sharpe ratio of the equally weighted stock index is only marginally higher.

Conversely, the infrastructure index does reflect a higher level of performance at all horizons when smaller projects and firms are given more weight, but its risk measure is drastically reduced, suggesting that constituent-level risk is much more idiosyncratic and therefore diversifiable than in the case of public equities.

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The very high Sharpe ratios of the equally weighted infrastructure index reflect this: at 3 to 3.5, they are a reflection of the very high illiquidity of the asset class. Indeed, a highly diversified portfolio of infrastructure equity with such a high Sharpe ratio is not for sale anywhere!

Figure 19b shows the cumulative performance of the private infrastructure index against the public equity reference, confirming that equal weighting delivers a higher historical performance than the value-weighted index.

### 4.2.2 Projects vs. 'Infrastructure Corporates'

We turn to the two subparts of the broad market infrastructure index: infrastructure project finance (panel B) and infrastructure corporates (Panel C) in tables 5 and 6.

Independently of the weighting scheme, project finance tends to outperform both infrastructure corporates and the reference public market index at all but one reported horizon.

Next, we focus on equally weighted infrastructure indices in table 6, allowing a more direct comparison since value weights are differently distributed in the project and corporate subsamples and the latter is much less concentrated than the former.

At the 10-year investment horizon, infrastructure projects (panel B) exhibits annualized equity returns of 15.47%, followed by infrastructure corporates (panel C) at 12.13% and the public equity market at 7.36% (panel D). This ranking remains true at shorter horizons.

The return volatility of projects (panel B) is also around 200 bps lower than that of infrastructure corporates (panel C).

As a result, the Sharpe ratios (SR) of the project index are significantly higher (100-170 bps) than those of the infrastructure corporates index.

Both infrastructure projects and corporates, however, have Sharpe ratios higher than the public equity reference index.

Performance on a cumulative basis is illustrated by figures 19a and 19b. Infrastructure projects clearly outperform infrastructure corporates and drive most of the additional performance obtained from the equal-weighting scheme.

The more favourable risk/reward trade-off of infrastructure projects is also visible in figures 20a and 20b. On an equally weighted basis, the SR of the project index is the major factor in the SR of the broad market index, whereas the SR of infrastructure corporates is not always higher than that of the SR of the public equity reference index.

### 4.2.3 Infrastructure Business Models

Turning to the value-weighted and equally weighted performance and SRs of the contracted, merchant, and regulated infrastructure indices, as shown on figures 21a,

# 4. Results

Figure 18: Annual performance: EDHEC*infra* **broad market** private infrastructure index, Europe(14), 2000-2016

(a) value-weighted | (b) equally weighted

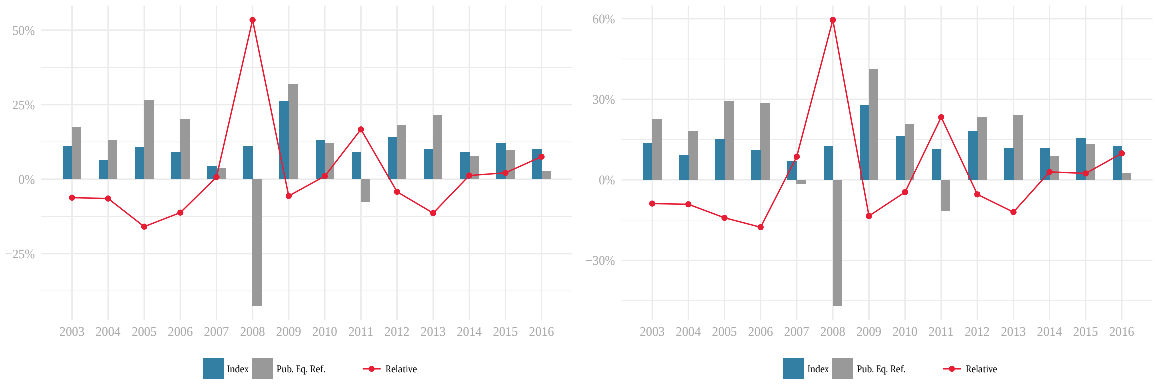



Figure 19: Cumulative performance: EDHEC*infra* **broad market** private infrastructure index, Europe(14), 2000-2016

(a) value-weighted | (b) equally weighted

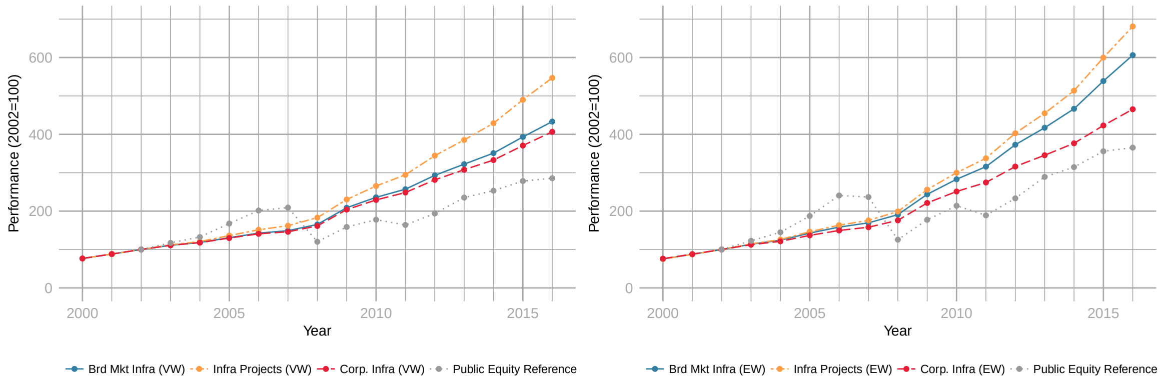
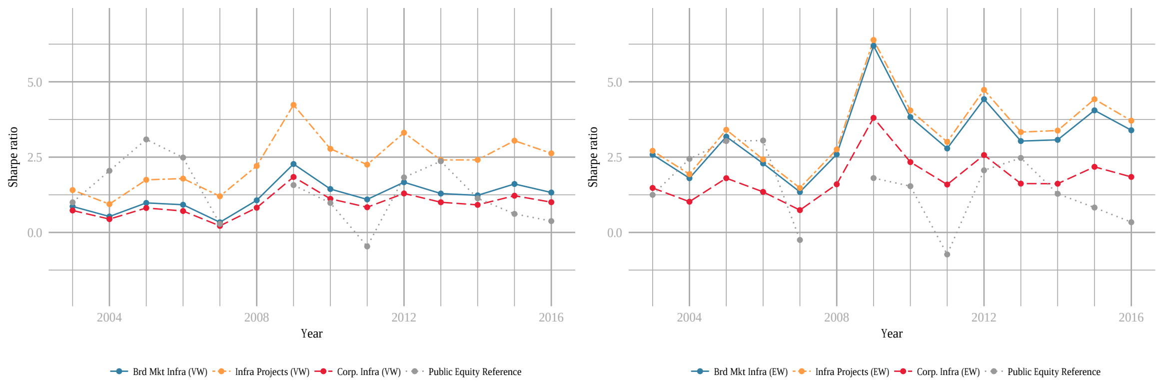



Figure 20: Sharpe ratios: EDHEC*infra* **broad market** private infrastructure index, Europe(14), 2000-2016

(a) value-weighted | (b) equally weighted



# 4. Results

Figure 21: Cumulative performance: EDHEC*infra* contracted, merchant, and regulated infrastructure indices, Europe(14), 2000-2016

(a) value-weighted (b) equally weighted

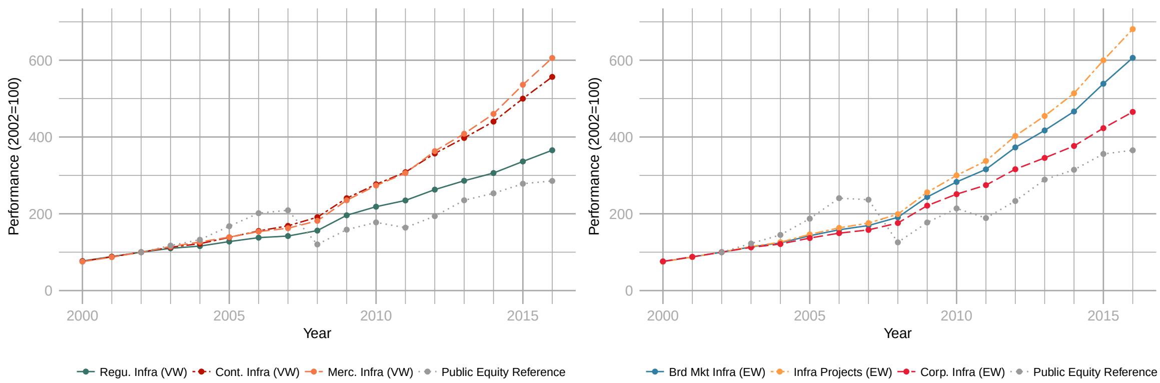
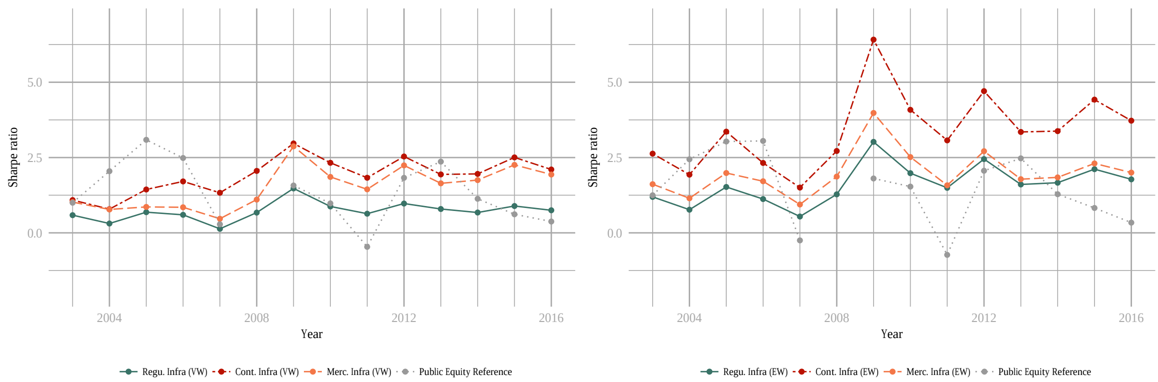



Figure 22: Sharpe ratios: EDHEC*infra* Contracted, merchant, and regulated infrastructure indices, Europe(14), 2000-2016

(a) value-weighted (b) equally weighted




21b, 22a, and 22b, respectively, a complementary picture emerges.

Contracted and merchant infrastructure, two categories including most projects in the sample, exhibit higher market outperformance than the regulated index, which includes mostly corporates.

On a value-weighted basis, the annual SR of the regulated index is even more comparable to the public market's. This is also shown in table 7.

On an equally weighted basis, contracted infrastructure is found to create the largest part of the risk-adjusted market outperformance, as shown in figure22b, whereas the SR of merchant and regulated infrastructure are, again, comparable to those of the public equity market index.

Thus, it is likely that it is **contracted infrastructure projects** that have contributed most of the broad market index outperformance, especially on an equally weighted basis.

# 4. Results

#### 4.2.4 Internal Rates of Return

Another, and the most commonly used, measure of performance in private equity investment is the internal rate of return or IRR: a "money-weighted" computation that tends to be more directly comparable with value-weighted index results.

Figures 23a and 23b show the IRR of the broad market, project, and corporate infrastructure indices and the IRR of the contracted, merchant, and regulated indices, respectively.

A flat or increasing trend in IRRs until 2006-2007 is followed by a decreasing tendency in all IRR measures since 2008. This is consistent with the general pattern of returns and the evolution of the risk-free rate over the period of interest.

Infrastructure projects still have the highest, IRRs but it is merchant infrastructure that tends to have the highest internal rates of return.

These IRRs are computed at the portfolio level (i.e., using inflows and outflows, realised and forecasted). Perhaps counter-intuitively, they tend to be lower than the time-weighted returns that we reported earlier.

The reason for this apparent discrepancy is simple: on the one hand, by design the IRR implies (exponentially) increasing per-period discount factors; on the other, we use a term structure of discount rates that adjusts each periodic discount factor to the level of (conditional) cash flow risk estimated in that period.

As a result, if future cash flow or payout volatility is expected to *decrease*, as is the case with a number of infrastructure projects, the future per-period discount factors used are lower than what is implied by the IRR calculation.

In other words, the approach we take to cash flow discounting (see Blanc-Brude and Hasan, 2015, for a full discussion) allows taking into account future payouts as well as expected capital gains, due to the lower level of discounting (conditionally) required for future payouts.

As a result, while the infrastructure equity broad market IRR is 7% in 2016, the same index returned 12.5% in that year, in part due to the decreasing level of payout risk of index constituents. Other drivers of this higher rate of return are duration and "market conditions" in that year.[15]

15 - The EDHEC*infra* website shows such a factor decomposition.

### 4.3 Extreme Risk Metrics

Turning to extreme risk metrics, the value-at-risk (VaR, 99.5%, Gaussian) of the six indices is shown on figures 24 and 25 for value- and equally weighted portfolios, respectively.

The same hierarchy exists between the different indices as before: projects and contracted infrastructure equity have the lowest VaR (lower than 20%), while corporate and especially regulated infras-

# 4. Results

Figure 23: IRR: EDHEC*infra* indices, Europe(14), 2000-2016

(a) broad market, projects, and corporates | (b) contracted, merchant, regulated

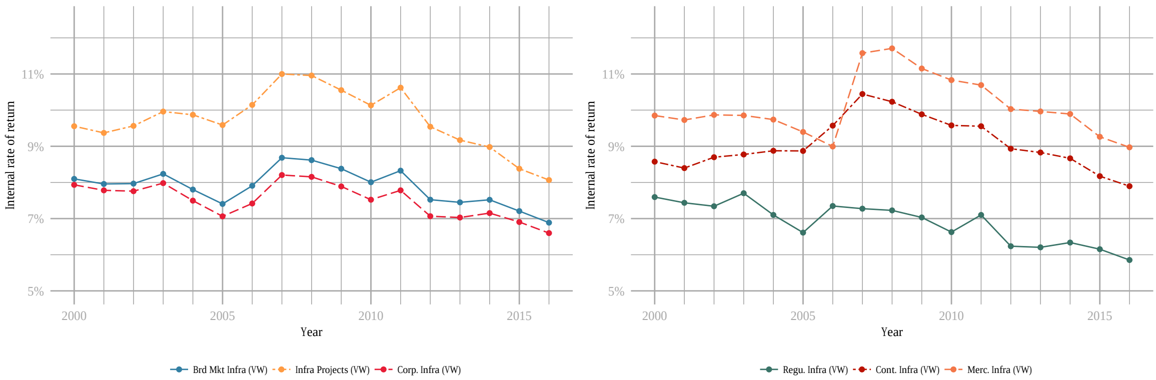
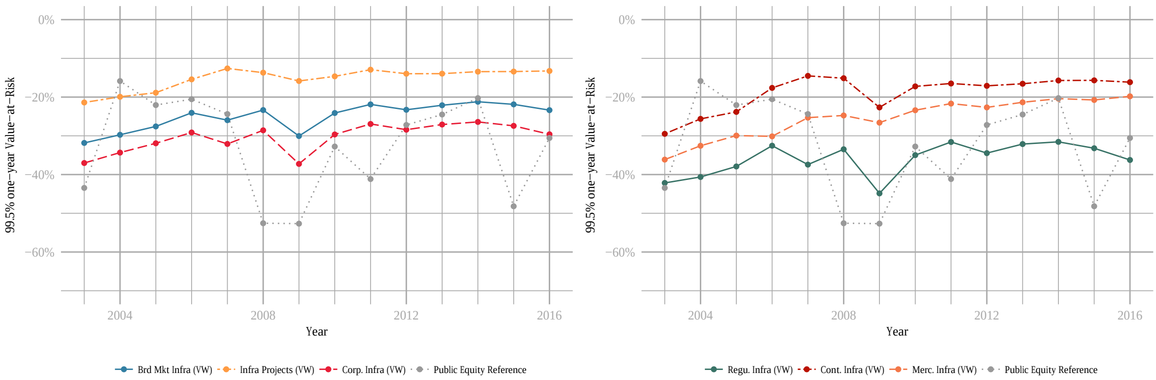



Figure 24: Value-at-risk*: **value-weighted** private infrastructure equity indices, Europe(14), fully hedged, 2000-2016

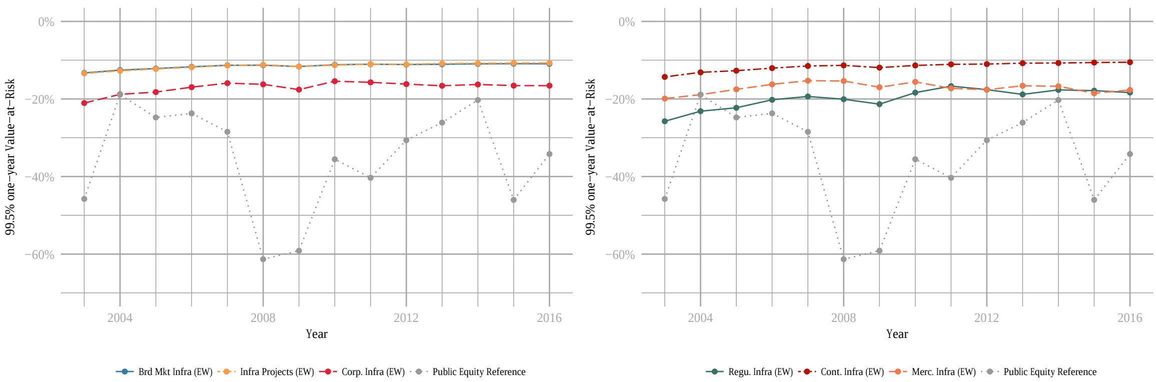
(a) broad market, projects, and corporates | (b) contracted, merchant, regulated




*99.5% one-year Gaussian value-at-risk

Figure 25: Value-at-risk*: **equally weighted** private infrastructure equity indices, Europe(14), fully hedged, 2000-2016

(a) broad market, projects, and corporates | (b) contracted, merchant, regulated




*99.5% one-year Gaussian value-at-risk

# 4. Results

tructure exhibit a higher level of VaR on a value-weighted basis, sometimes higher or on par with the public equity market, with the notable exception of the 2008-2009 drop which characterises the equity market reference index.

On an equally weighted basis, the level of VaR is much reduced and is, as before, driven by contracted projects, which play a much larger role in the performance of this type of index.

## 4.4 The Role of Portfolio Diversification

Finally, as the difference between value- and equally weighted portfolios suggests, the impact of portfolio diversification must be taken into account when interpreting these results.

Figure 26 shows the distribution of asset-level return volatilities over the entire observation period. Our asset-level volatilities are not "smoothed"[16] and can in fact be quite high, sometimes higher than 100%.

Indeed, one of the results of our cash flow modeling and forecasting for equity investors is that equity payouts are quite variable both in size and frequency.

In fact, in a number of "bad years" certain firms in our index sample experience very large losses (e.g., toll roads in Spain and power plants in the UK between 2007 and 2009.

However, risk measures are considerably reduced at the index level, as shown in figures 27a and 27b, due to the highly idiosyncratic nature of the volatility of infrastructure assets. Hence, as assets are aggregated in value-weighted and equally weighted portfolios, the average level and the dispersion of portfolio risk measures are considerably reduced.

Figure 28 shows the relationship between the effective number of bets (defined above) of each of the 192 EDHEC*infra* private infrastructure equity indices in 2016 and the volatility of each index, which combines the weighted return volatility of each index constituent with a pair-wise covariance matrix of asset returns.

In value-weighted portfolios, the effective number of bets (ENB) is lower than the number of portfolio constituents. In an equally weighted portfolio, by design the ENB must be equal to the number of constituents.

Figure 28 shows that the impact of diversification on the portfolio risk measure is significant and confirms that the higher Sharpe ratios achieved by contracted and project indices as well as equally weighted indices are the result of lower risk measures achieved through diversification at the portfolio level.

In effect, diverification between infrastructure equity firms is strong enough to offset any individual firm negative returns (in bad years) or drawdown. Figure 29 shows

16 - A frequent issue with private investment studies due to the stale pricing problem (see Woodward, 2004, for a literature review and discussion in the contest of private equity).

# 4. Results

Figure 26: Histogram of asset-level return volatilities within 192 EDHEC*infra* equity indices, 2000-2016

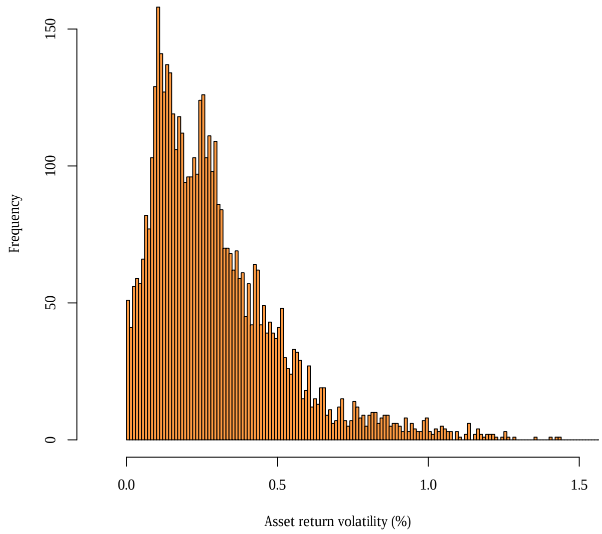
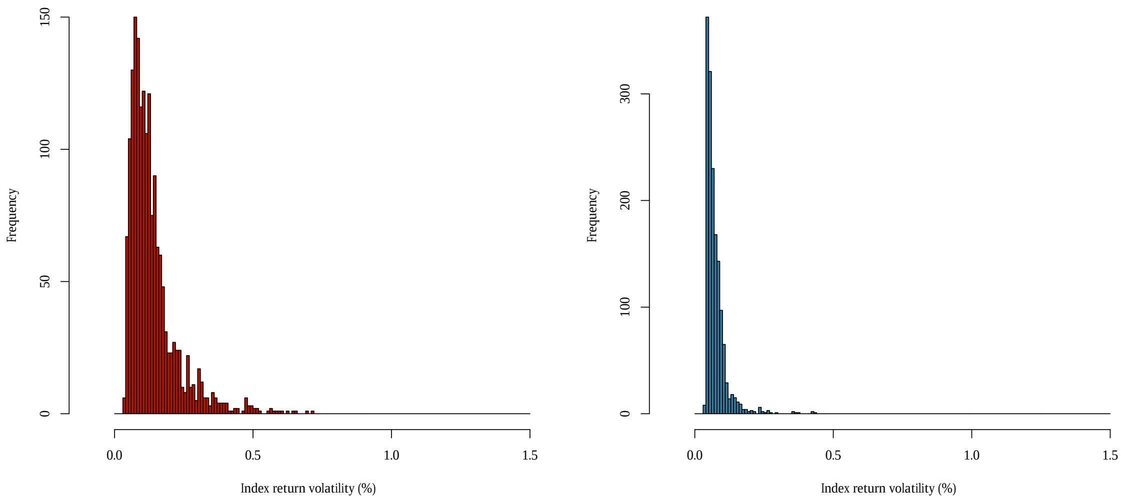



Figure 27: Histogram of index-level return volatilities within 192 EDHEC*infra* equity indices, 2000-2016

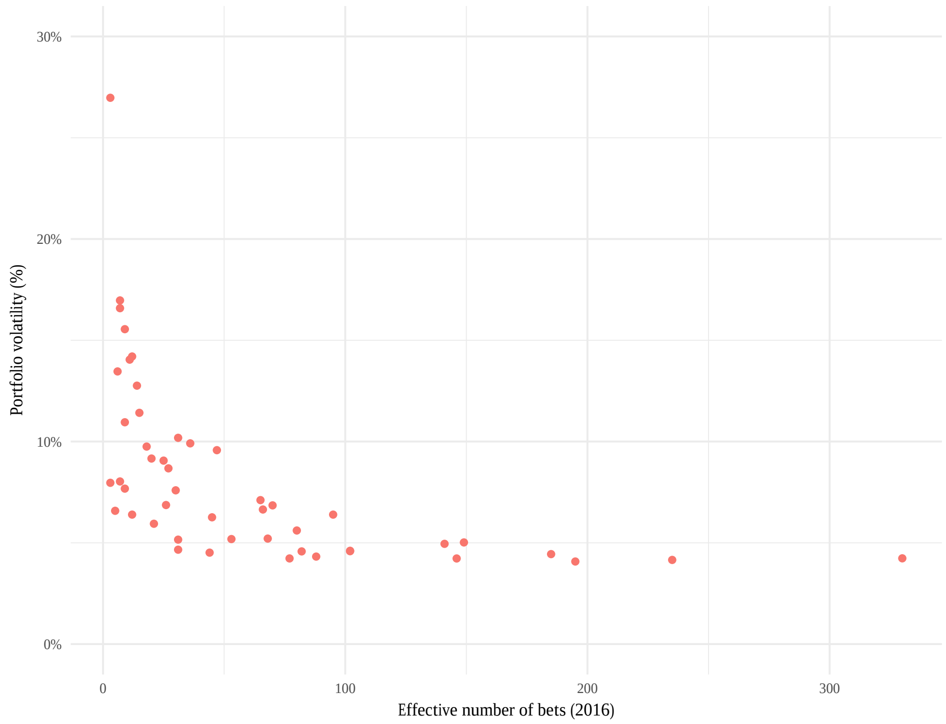
(a) value-weighted

(b) equally weighted



# 4. Results

Figure 28: Effective number of bets and portfolio risk measure in 192 EDHEC*infra* equity indices, 2016

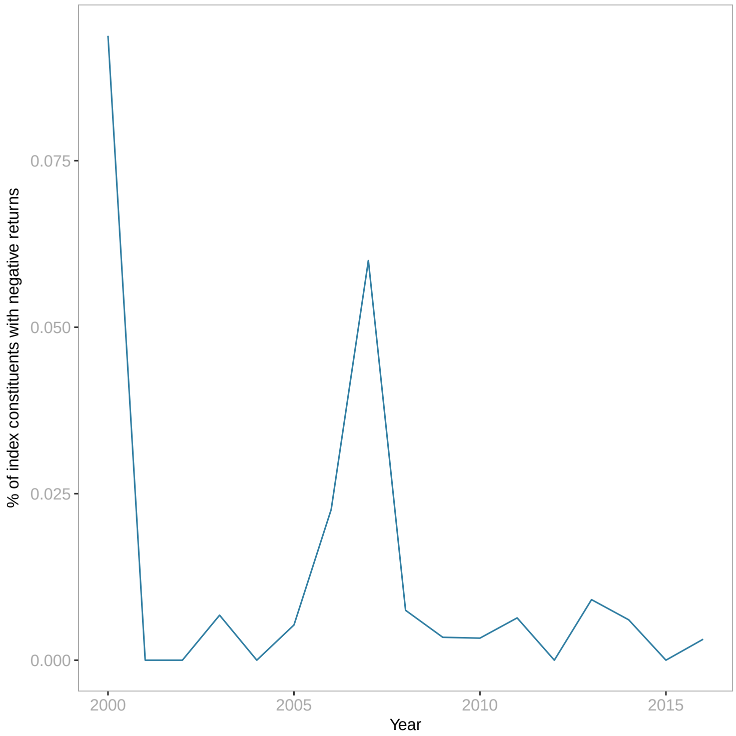



the percentage of firms reporting negative returns in the broad market indec in each year.

In 2007 for instance, more than 6% of the firms in the portfolio (by number) report negative returns, yet the index exhibits zero drawdown in that year.

# 4. Results

Figure 29: Percentage of firms with negative equity returns in the broad European market EDHEC*infra* equity index, 2000-2016



# 5. Conclusion

# 5. Conclusion

In conclusion, we can draw out a number of stylised facts with respect to our first two questions about the risk-adjusted performance of private infrastructure equity:

1. Our broad European market infrastructure equity index (including project and infrastructure corporates) significantly outperforms the European public equity reference index over the 2000-2016 period;
2. It also does not suffer from any drawdown during the 2007-2008 and 2010-2011 periods of stock market collapse, as shown on figure 4;
3. This is due to the high level of diversification of firm-specific risk within the infrastructure indices. Hence, while we observe numerous cases of losses at the project level, the index as whole maintains a positive performance in each year.
4. Figure 4a shows that it is infrastructure *projects*, rather than corporates that contribute most of the broad market performance.
5. Figure 4b suggests that merchant and contracted infrastructure contributed equally to this outperformance, however this is shown on a value-weighted basis, which tends to overweight larger projects. We note that on an equally weighted basis (not shown here), most of the outperformance comes from contracted infrastructure alone.
6. In figure 5, a secular trend of lower IRRs is visible, driven by higher equity valuations of private infrastructure firms over the period. We note that infrastructure projects have significantly higher IRRs than infrastructure corporates (figure 5a) and that merchant infrastructure also tends to have higher IRRs than contracted or regulated infrastructure (figure 5b).
7. These IRRs are computed in the usual manner using all realised and forecasted equity cash flows for all index constituents. It should be noted that the time-weighted returns computed tend to be higher than the index IRRs. The IRR, which is a money-weighted computation, should really be compared with the value-weighted index returns. The IRR also implies (by design) increasing per-period discount factors, whereas we estimate a term structure of discount factors which reflect the derisking of infrastructure investments over time. As a result, reported time-weighted returns include a share of expected capital appreciation, which the standard IRR formula cannot capture.

Our broad European market private infrastructure equity index compares favourably to a public equity reference index. It provides greater performance and lower risk, including lower value-at-risk (not shown here). As a result, it exhibits an attractive risk-reward profile.

Moreover, certain segments of the private infrastructure universe have contributed most of this performance, namely, infrastructure projects and contracted infrastructure.

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The latter two often overlap and, as well as corresponding to a relatively lower-risk business model, they tend to be smaller in size than other infrastructure firms. Hence, indices built with such assets tend to diversify better and faster. This effect leads to higher returns and lower portfolio risk measures.

Our third question was concerned with the role of diversification in private infrastructure investment portfolios.

Diversification is always desirable, but it can come at a cost when assets are bulky, deal times long and uncertain, and fixed transaction costs high. As a result, most infrastructure funds make between 6 and 12 investments in their lifetime, and asset owners favouring so-called direct investment tend to make large transactions and to own between a dozen and a few dozen infrastructure assets (see Blanc-Brude, 2013, for a discussion).

Having built broad market indices including hundreds of assets in some cases, we can now observe the impact of diversification on infrastructure portfolios of various sizes and degrees of concentration.

We can also observe the difference between two ideal-type weighting schemes: on a value-weighted basis, the index represents "the market" in the standard acceptance of the term; on an equally weighted basis, each constituent makes exactly the same contribution to index performance at all times.

Today, neither of these strategies are accessible to asset owners or managers. Nevertheless, they provide us with a better understanding of the upper and lower limits of what infrastructure investors might expect from greater portfolio diversification.

Figure 6 shows the distribution of asset-level return volatilities over the entire observation period. We note that the asset-level volatilities we measure are not "smoothed" [17] and can in fact be quite high, sometimes higher than 100%. Indeed, one of the results of our cash flow modeling and forecasting for equity investors is that infrastructure equity payouts are quite variable both in size and frequency.

Instead, risk measures are considerably reduced at the index level, due to the highly idiosyncratic nature of the volatility of infrastructure assets. Hence, as assets are aggregated in value-weighted and equally weighted portfolios, the average level and the dispersion of portfolio risk measures are considerably reduced.

Figure 7 shows the relationship between the effective number of bets [18] of each of the 192 EDHEC*infra* private infrastructure equity indices in 2016 and the standard portfolio risk measure of each index, which combines the weighted return volatility of each index constituent with a pair-wise covariance matrix of asset returns.

In value-weighted portfolios, the ENB is lower than the number of portfolio constituents. In an equally weighted

17 - A frequent issue with private investment studies due to the stale pricing problem (see Woodward, 2004, for a literature review and discussion in the contest of private equity).

18 - A measure of portfolio concentration equal to the inverse of the Herfindahl-Hirschman index, that is, the sum of squared weights (see Meucci et al., 2013).

# 5. Conclusion

portfolio, by design the ENB must be equal to the number of constituents.

Figure 7 confirms that the impact of diversification on the portfolio risk measure is significant and that the higher Sharpe ratios achieved by contracted and project indices as well as equally weighted indices are the result of lower risk measures achieved through diversification at the portfolio level.

We note that substantial risk reduction appears beyond 50 constituents, a number of assets that few infrastructure asset owners or manager can hope to achieve today.

Indeed, achieving such levels of portfolio diversification is a genuine challenge. Building a large portfolio of infrastructure assets requires a large budget and can take many years.

Moreover, investing on an equally weighted basis, let alone using a more risk-efficient weighting scheme, is virtually impossible given the heterogeneity of deal sizes and the discrepancy between the illiquidity of individual constituents and the frequent rebalancing requirements of equally weighted schemes.

Still, these results show that achieving only limited levels of portfolio diversification is not a trivial problem for investors. The opportunity cost of not doing so in a private infrastructure equity portfolio may in fact be very large as well.

In the absence of well-diversified infrastructure products, most infrastructure investments thus become very active, concentrated bets, and it becomes much more difficult for investors to have a view on infrastructure investment at the asset allocation level.

## Tomorrow: The Need for Investable Solutions

With these results, which will continue to be updated and expanded over the coming years, we created the ability to measure the risk-adjusted performance of private infrastructure equity investments on a comparable basis with other asset classes.

This research allows asset owners and managers to begin to evaluate how they might better access infrastructure investments, so that infrastructure investing can become a means to an end and help them meet their investment goals.

The idiosyncratic nature of risk in infrastructure investment is one of the initial appeals of what we called the "infrastructure investment narrative" (Blanc-Brude, 2013): infrastructure businesses are expected to exhibit low correlation with the business cycle and help diversify the rest of the portfolio.

But the large and illiquid nature of these investment also creates an significant diversification challenge within the asset class; one that asset owners should not ignore. In effect, the coveted investment narrative,

# 5. Conclusion

which our broad market indices confirm the existence of, may seem slightly out of reach to most investors if it requires being exposed to hundreds of infrastructure assets.

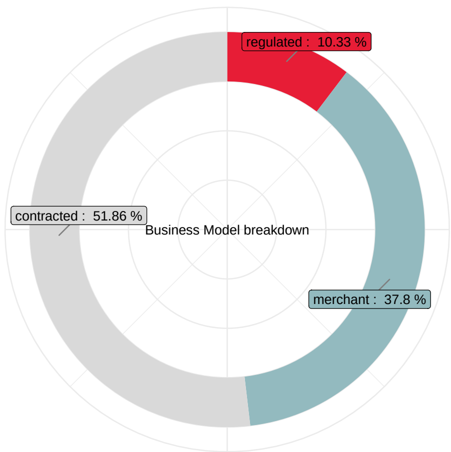
Delivering the infrastructure investment narrative to investors will require the development of new investment products and solutions that can create exposure to a broad base of assets and, at least in part, aim to replicate the characteristics of the infrastructure market.

# 6. Appendix

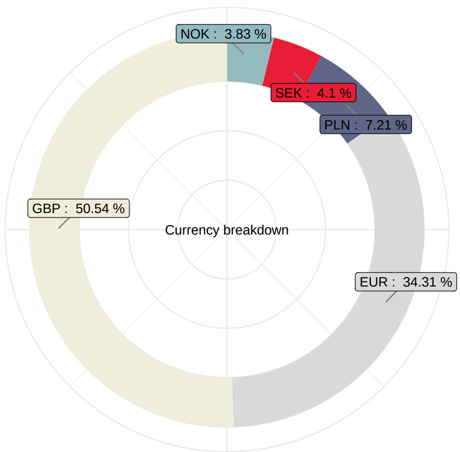
# 6. Appendix

Figure 30: EDHEC*infra* private **infrastructure project** index, fully hedged, 2016 breakdown by market value, **value-weithed**

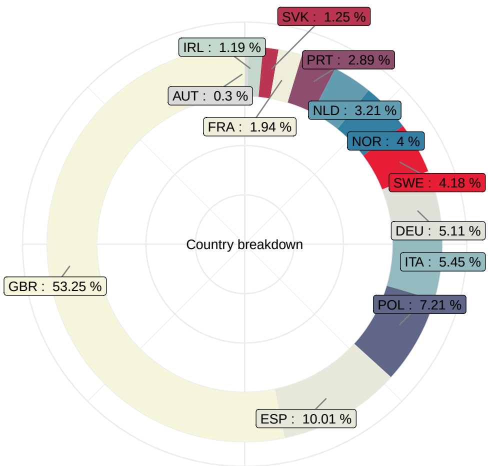
(a) business model breakdown



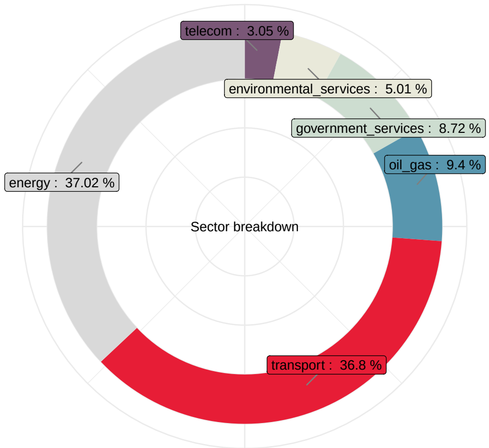

(b) currency breakdown




(c) country breakdown



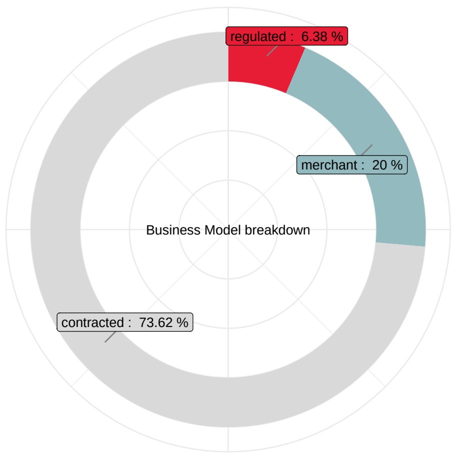

(d) sector breakdown



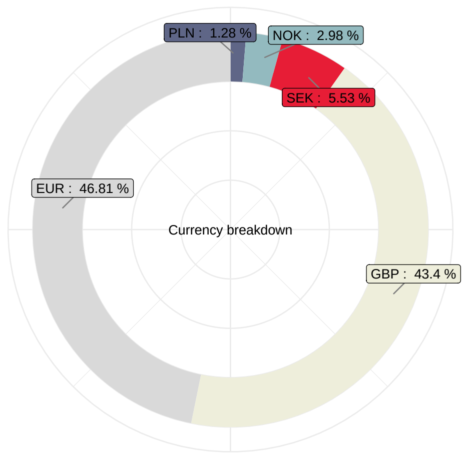
# 6. Appendix

Figure 31: EDHEC*infra* private **infrastructure project** index, fully hedged, 2016 breakdown by market value, **equally weighted**

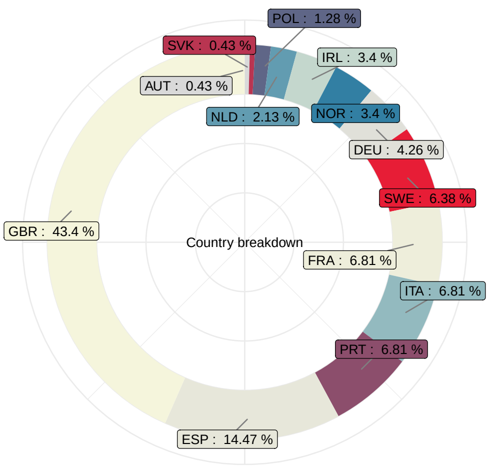
(a) business model breakdown



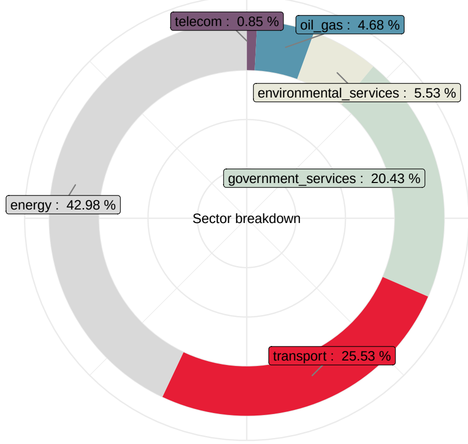

(b) currency breakdown




(c) country breakdown



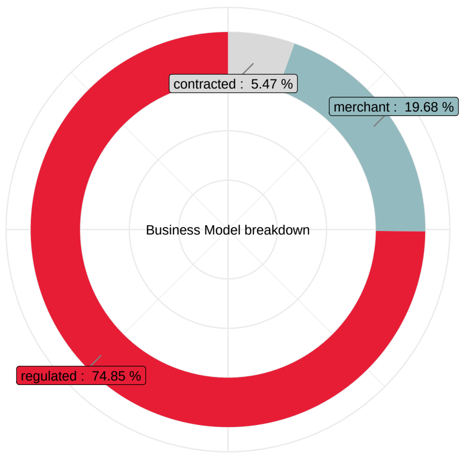

(d) sector breakdown



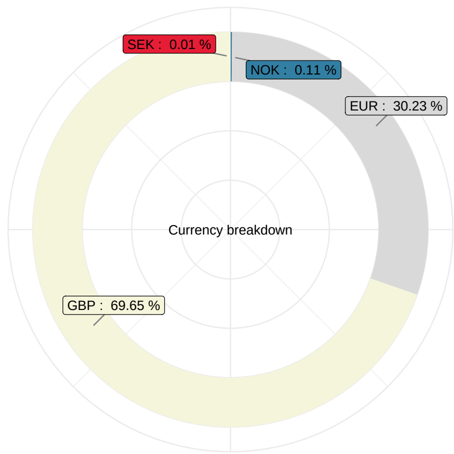
# 6. Appendix

Figure 32: EDHEC*infra* **corporate infrastructure** index, fully hedged, 2016 breakdown by market value, **value-weighted**

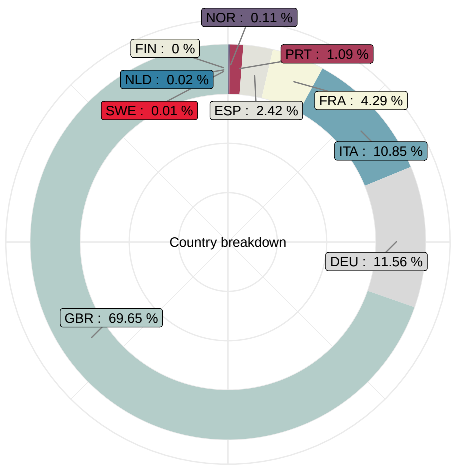
(a) business model breakdown



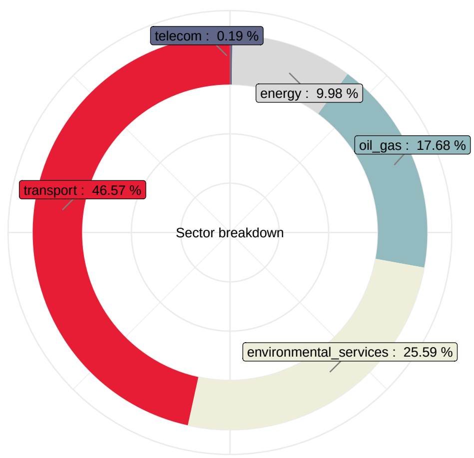

(b) currency breakdown




(c) country breakdown



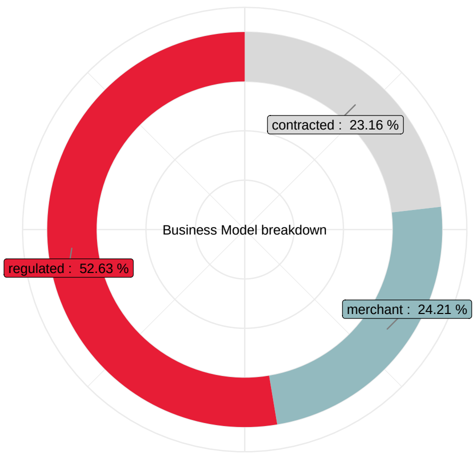

(d) sector breakdown



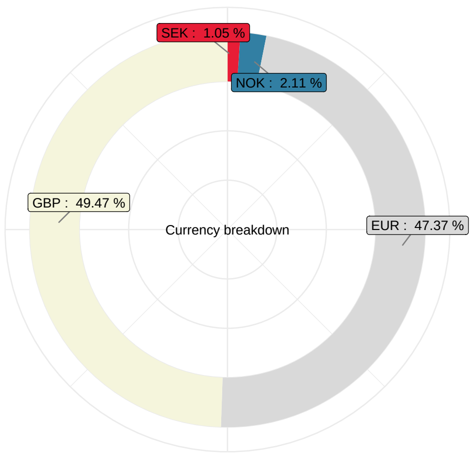
# 6. Appendix

Figure 33: EDHEC*infra* **corporate infrastructure** index, fully hedged, 2016 breakdown by market value, equal weights

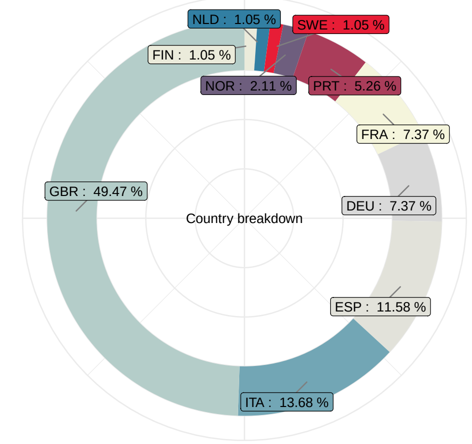
(a) business model breakdown



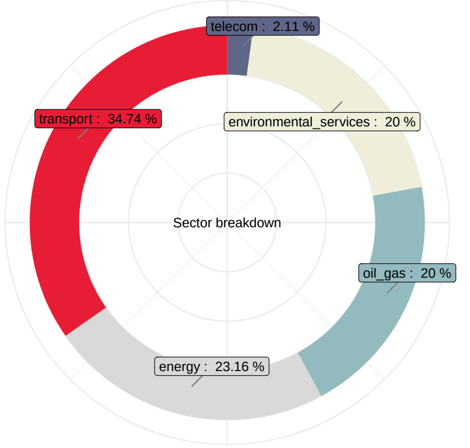

(b) currency breakdown




(c) country breakdown

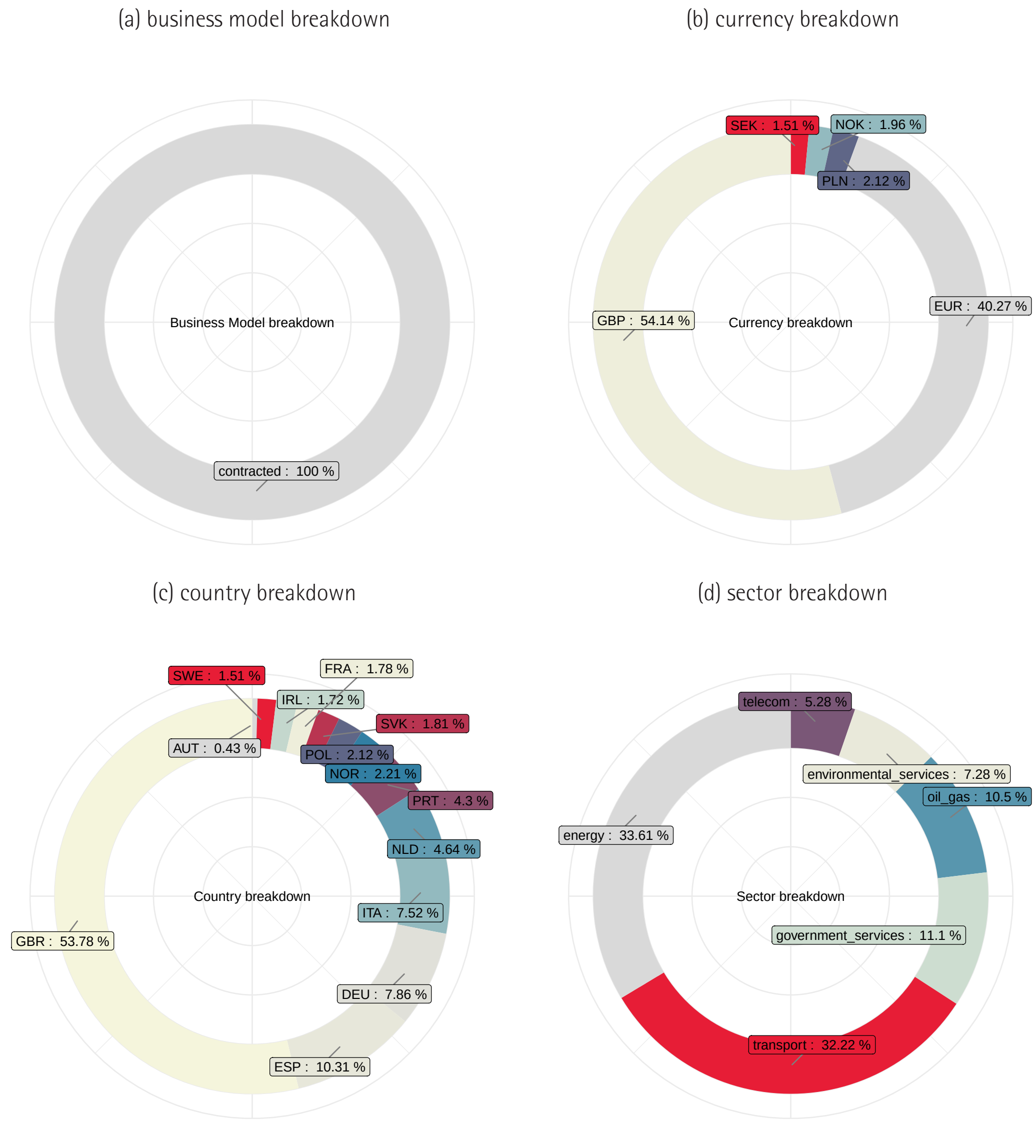



(d) sector breakdown



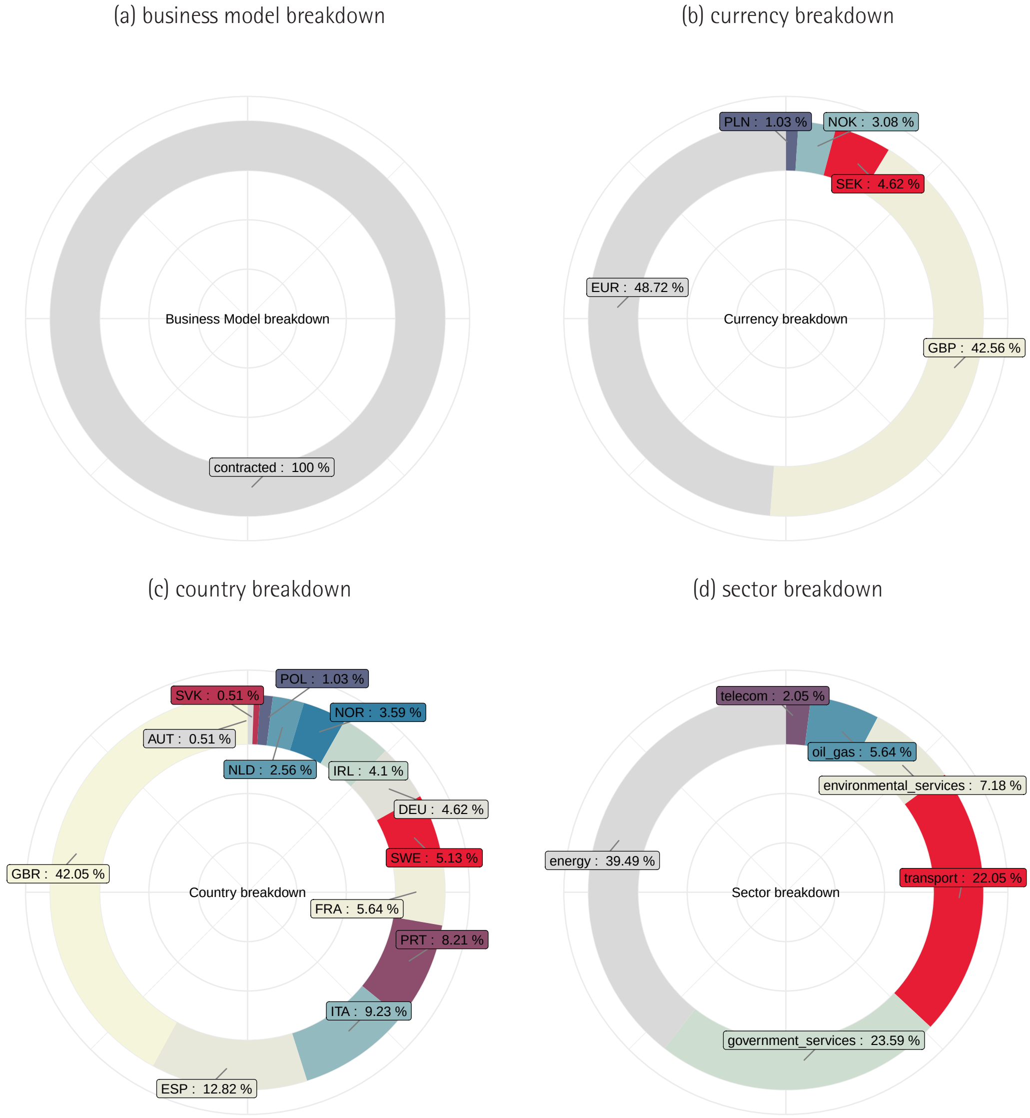
# 6. Appendix

Figure 34: EDHEC*infra* **contracted infrastructure** index, fully hedged, 2016 breakdown by market value, **value-weighted**



# 6. Appendix

Figure 35: EDHEC*infra* **contracted infrastructure** index, fully hedged, 2016 breakdown by market value, equally weighted



# 6. Appendix

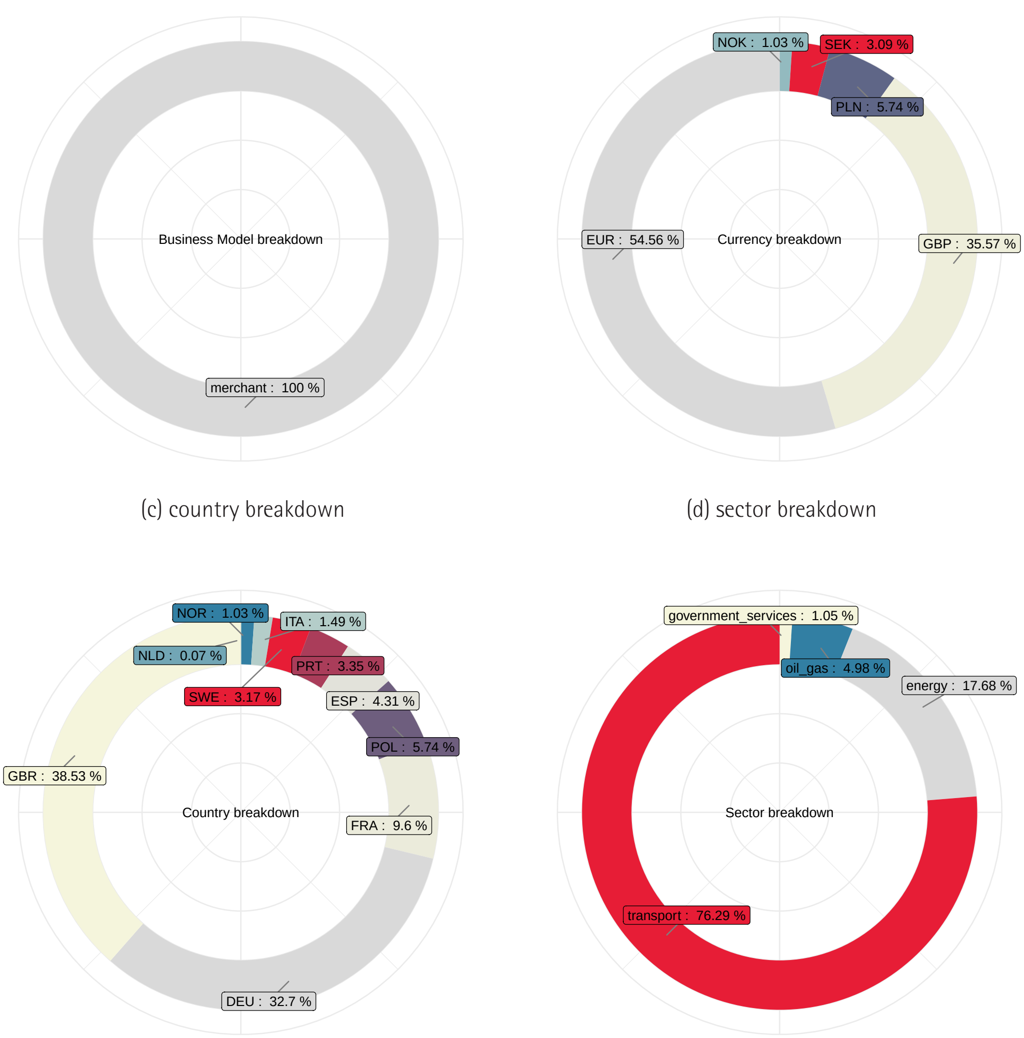
Figure 36: EDHEC*infra* **merchant infrastructure** index, fully hedged, 2016 breakdown by market value, **value-weighted**

(a) business model breakdown

(b) currency breakdown

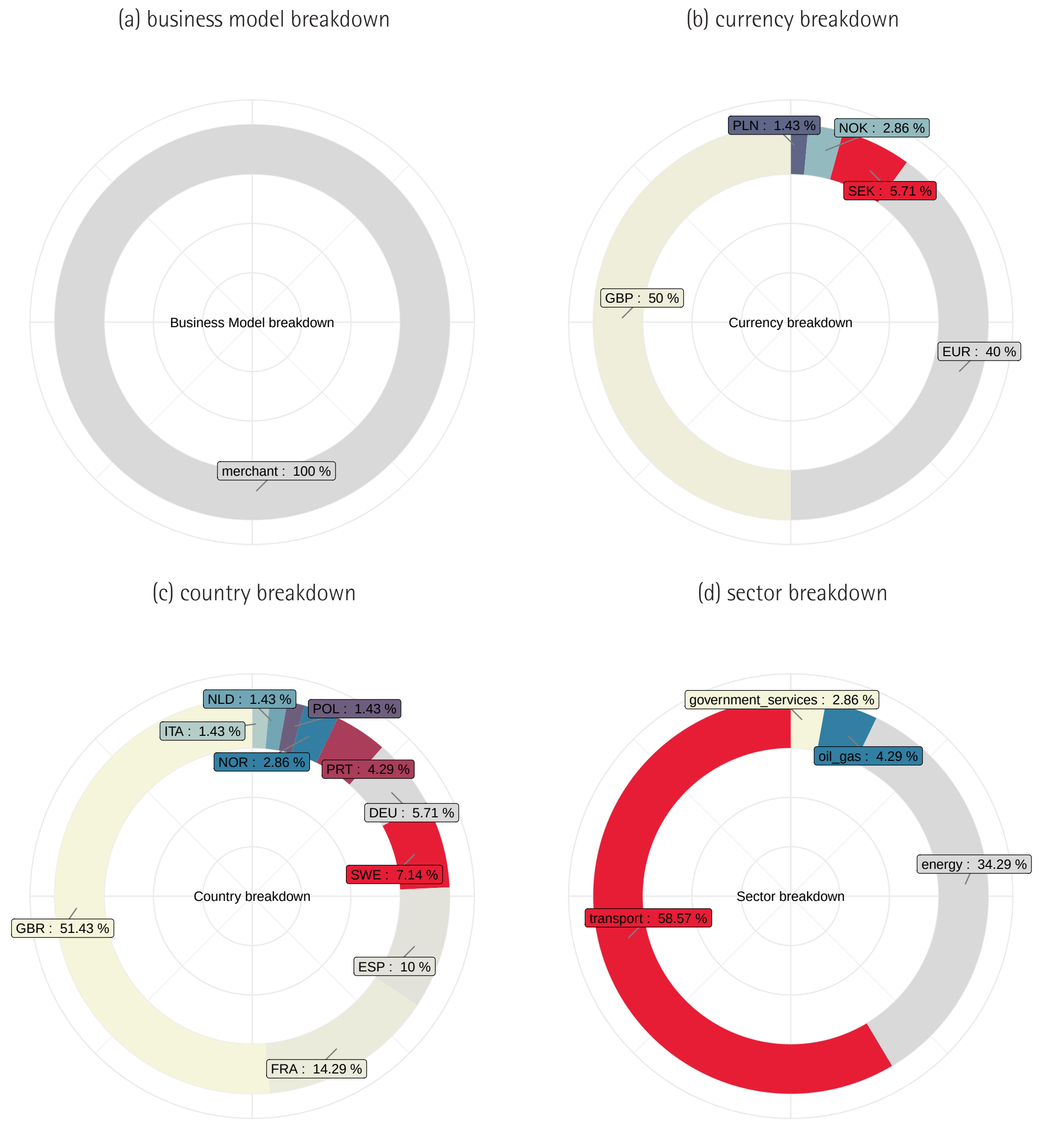
(c) country breakdown

(d) sector breakdown



# 6. Appendix

Figure 37: EDHEC*infra* **merchant infrastructure** index, fully hedged, 2016 breakdown by market value, equally weighted

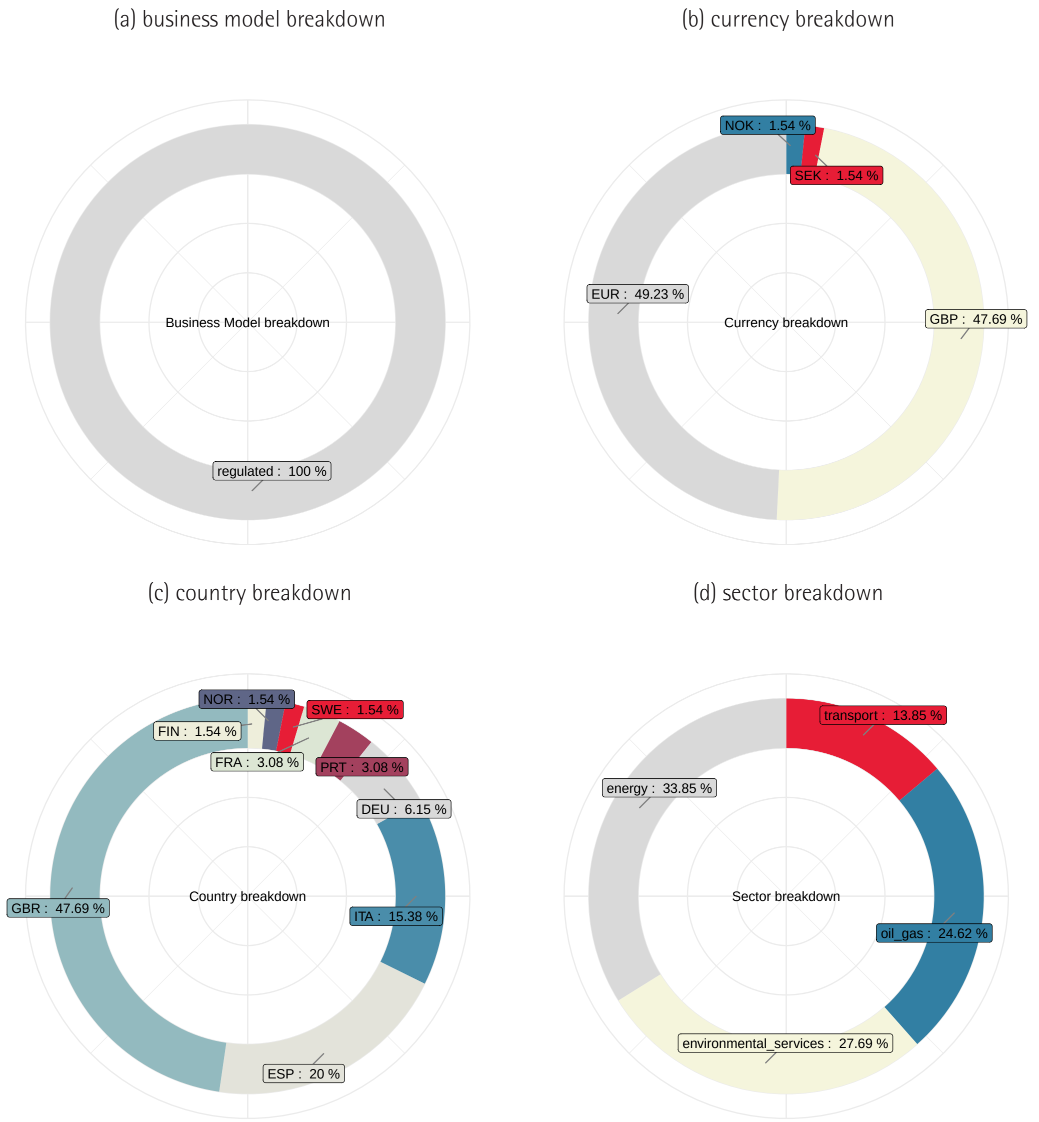


# 6. Appendix

Figure 38: EDHEC*infra* **regulated infrastructure** index, fully hedged, 2016 breakdown by market value, **value-weighted**

# 6. Appendix

Figure 39: EDHEC*infra* **regulated infrastructure** index, fully hedged, 2016 breakdown by market value, equally weighted



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# About Campbell Lutyens

# About Campbell Lutyens

Campbell Lutyens is an independent advisory firm founded in 1988 focused on fund placement and secondary advisory.

In its fund placement practice, it focuses on raising capital globally from limited partners and providing specialist advice to general partners. In its secondary advisory practice, it advises limited partners and general partners on providing liquidity solutions through the sale or restructuring of portfolios of fund or direct investments.

The firm has offices in London, New York and Hong Kong and comprises a team of over 80 international executives, advisors and staff with global and broad-ranging expertise in the private equity, infrastructure and private debt sectors.

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# About Long-Term Investors Club

# About Long-Term Investors Club

In 2009 Caisse des Dépots, Cassa Depositi e Prestiti, the European Investment Bank and Kreditanstalt für Wiederaufbau created the Long-Term Investors Club (LTIC) with the aim of bringing together major worldwide institutions to emphasis common identity as long-term investors, to encourage cooperation and to foster the right conditions for long-term investments in promoting growth. Today the Long-Term Investors Club gathers 18 major financial institutions and institutional investors from all over the world mainly from G20 countries, representing a combined balance sheet total of USD 5.4 trillion.

The LTIC has done much progress since its foundation to foster long-term investment not only in the EU but globally. Cooperation among members has developed sensibly and policy makers, at the European and G20 level, are increasingly aware of the role LTIs can play.

We believe that a long-term vision of finance and economy represents a real change of paradigm to get a strong, sustainable and balanced growth in global economy

Club
LONG-TERM
INVESTORS

# About Long-Term Infrastructure Investors Association

# About Long-Term Infrastructure Investors Association

Founded in 2014 by investors and for investors, Long Term Infrastructure Investors Association works with a wide range of stakeholders, including infrastructure investors, policy-makers, and academia, on supporting long-term, responsible deployment of private capital to public infrastructure around the world.

Our principal activities include:
- Public advocacy and engagement with policy-makers;
- Investment in research and innovation for the benefit of infrastructure investors;
- Education and training on long-term investing in infrastructure.

LTIIA is a not-for-profit international association and most of our members are institutional investors and fund managers with responsibilities over long-term and open-ended infrastructure investment mandates. LTIIA is a Network Supporter of UN-PRI.

LTI/A | Long-term Infrastructure Investors Association

# About EDHEC Infrastructure Institute-Singapore

# About EDHEC Infrastructure Institute-Singapore

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

## Origins

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

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

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

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

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

## A Profound Knowledge Gap

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

Capturing these benefits, however, requires answering some difficult questions:

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

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

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

## Mission Statement

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

We aim to deliver the best available estimates of financial performance and risks of reference portfolios of privately held infrastructure investments and to provide

# About EDHEC Infrastructure Institute-Singapore

investors with valuable insights about their strategic asset allocation choices in infrastructure, as well as to support the adequate calibration of the relevant prudential frameworks.

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

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

## What We Do

The EDHEC*infra*team is focused on three key tasks:

1. **Data collection and analysis**: we collect, clean, and analyse the private infrastructure investment data of the project's data contributors as well as from other sources, and input it into EDHEC*infra*'s unique database of infrastructure equity and debt investments and cash flows. We also develop data collection and reporting standards that can be used to make data collection more efficient and more transparently reported. This database already covers 15 years of data and hundreds of investments and, as such, is already the largest dedicated database of infrastructure investment information available.

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

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

## Partners of EDHEC*infra*

### Monetary Authority of Singapore

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

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

### Sponsored Research Chairs

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

# About EDHEC Infrastructure Institute-Singapore

1. The EDHEC/NATIXIS Research Chair on the Investment and Governance Characteristics of Infrastructure Debt Instruments, 2012-2015
2. The EDHEC/Meridiam/Campbell Lutyens Research Chair on Infrastructure Equity Investment Management and Benchmarking, 2013-2016
3. The EDHEC/NATIXIS Research Chair on Infrastructure Debt Benchmarking, 2015-2018
4. The EDHEC/Long-Term Infrastructure Investor Association Research Chair on Infrastructure Equity Benchmarking, 2016-2019
5. The EDHEC/Global Infrastructure Hub Survey of Infrastructure Investors' Perceptions and Expectations, 2016-2017

## Partner Organisations

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

- The Global Infrastructure Hub;
- The European Investment Bank;
- The World Bank Group;
- The European Bank for Reconstruction and Development;
- The members of the Long-Term Infrastructure Investor Association;
- Over 20 other North American, European, and Australasian investors and infrastructure managers.

## EDHEC*infra* is also :

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

# EDHEC Infrastructure Institute Publications

# EDHEC Infrastructure Institute Publications

## EDHEC Publications


- Blanc-Brude, F., A. Chreng, M. Hasan, Q. Wang, and T. Whittaker. "Private Infrastructure Equity Indices: Benchmarking European Private Infrastructure Equity 2000-2016" (June 2017).
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