A Publication of the EDHEC Infrastructure Institute-Singapore

Private Infrastructure Debt Broad Market Indices

Benchmarking Europe's Private Infrastructure Debt Market 2000-2016

June 2017

with the support of

NATIXIS
BEYOND BANKING

EDHECinfra
Singapore Infrastructure Investment Institute

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The authors would like to thank Noël Amenc and Anne-Christine Champion for useful comments and suggestions; the EDHEC*infra* data team for its invaluable contribution to this project: Sharyn Chang, Silvia Garcia, Christy Tran, and Jing-Li Yim; and Terrance Teoh for keeping the data safe. Financial support from Natixis is acknowledged. This study presents the authors' views and conclusions which are not necessarily those of EDHEC Business School or Natixis.

Foreword

The purpose of the present publication, "Infrastructure Debt Index: Benchmarking Private European Infrastructure Debt 2000-2016," which is drawn from the Natixis research chair on infrastructure debt investment at EDHEC Infrastructure Institute-Singapore, is to describe the very first results of an ambitious project to create investment benchmarks for long-term investors in infrastructure.

This project was conceived several years ago at EDHEC-Risk Institute and has been gathering pace over the past two years with the creation of the EDHEC Infrastructure Institute, which now hosts a dedicated team that collects and aggregates primary data, designs new quantitative techniques to measure the performance of private, hyperilliquid assets like infrastructure debt, and creates tools to make this information available to asset owners and managers.

This paper looks at the risk-adjusted performance of a broad European market index of private, senior infrastructure debt and compares it to the listed senior corporate bond market. As such it provides the first empirical test of the proposition that private infrastructure debt has unique characteristics warranting a specific investment bucket as well as a specific prudential treatment.

Doing so, it also contributes to the currently unfinished debate about the definition of qualifying infrastructure assets. By comparing the contributions to this broad market index of limited-recourse project finance debt and that of what has become known as "infrastructure corporates" (e.g., utilities), this paper will contribute to a better, more robust definition of infrastructure investment for both investors and regulators.

The authors' findings suggest that a "naïve" filter that simply selects instruments on the basis of industrial classifications may fail to capture the effect anticipated in the infrastructure "investment narrative" defined by Blanc-Brude (2013).

This paper also marks the beginning of whole new stream of research based on the unique database – the largest in the world – of infrastructure investment data that has been created by EDHEC*infra*. Ultimately, this database will achieve global coverage, and over time, more ground-breaking research can be done that will revolutionise the way investors understand infrastructure investment.

We are grateful to Natixis for their support of this study in the context of this research chair since 2012.

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Executive Summary

Executive Summary

In this paper, we present the first results of a multiyear project to create and compute fully fledged private infrastructure debt investment benchmarks. The first version of these indices span 14 European countries over 16 years, going back to 2000. They are built from a representative sample by size and vintage of the private European infrastructure debt market, including hundreds of borrowers and debt instruments over that period.

In particular, we focus on what distinguishes infrastructure debt from corporate debt. When developing this research, we used two competing views of what defines infrastructure investment:

1. The first one equates infrastructure investment with "project finance" [1] and echoes the June 2016 advice of the European insurance regulator (EIOPA, 2016) to the European Commission to define "qualifying infrastructure" for the purposes of the Solvency-II directive;
2. The second view, also expressed during recent prudential regulatory consultations, defines infrastructure investment more broadly and proposes to include "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.

1 - i.e., the debt instruments used to finance project-specific firms that are expected to operate within very strict constraints over the life of a single investment project (e.g., a toll road or a power plant).

In this paper, we use the EDHEC*infra* database and technology to address two simple questions:

1. How does a "broad market" index of private infrastructure senior debt perform against an equivalent corporate senior debt index?
2. Is there a difference between the risk-adjusted performance of infrastructure "project finance" debt and that of "infrastructure corporates," and to what extent do these two subindices contribute to the performance of a broad market infrastructure debt index?

Answering these questions is instrumental to establishing the existence of an "infrastructure debt asset class," both from an asset-allocation and a prudential perspective, and to defining which types of instruments should qualify for a potential new bucket or prudential risk charge.

A Representative Sample of the Private Infrastructure Debt Market

Research using private data often suffers from multiple biases created by the source of data. To avoid this problem, when selecting constituents and collecting data, we take a "bottom-up" approach to identify individual firms and instruments, and to collect the relevant data from a range of public and private sources.

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

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problem with studies involving privately sourced data. Here, the relevant firms and debt instruments are identified first and, in a second step, the relevant data is collected for a representative sample of the investable universe for which data can be collected.

In the investable infrastructure market identified, not all firms have outstanding senior debt provided by third party creditors (as opposed to the firm's shareholders). Of the 400 firms used to create a private infrastructure market sample, about 300 are found to have senior term debt provided by commercial banks, private loan investors, or bond holders. Together they represent more than a thousand individual credit instruments.

Over the 15-year period of study, our market sample represents 40-50% of the outstanding face value of infrastructure debt in Europe.

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*,[2] firms and instruments also have individual *attributes*,[3] 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 team of human analysts. Each firm's data is reviewed iteratively at three different levels of validation including computer-generated and human checks.

A Fully Fledged Performance Measurement Technology

Private infrastructure debt is seldom traded, and only a limited amount of market price data is observable. Hence, the risk-adjusted performance of the senior debt of each firm in the index sample is derived by forecasting cash flows to debt holders, taking into account future scenarios of default and restructuring, and discounting them on the basis of the volatility of future payouts and available price information (including the initial value of the investment and comparable transactions taking place each year).

Once each senior debt tranche 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. The latest "base case" senior debt service, i.e., future principal and debt repayments, is either obtained from data contributors or estimated using infor-

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

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

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mation available about each senior debt instrument present in the firm's capital structure (see section 3.2.1);

2. The mean and variance of the firm's debt service cover ratio (DSCR) are estimated for each firm in all realised periods and forecasted for the remainder of the firm's debt maturity (see section 3.2.2);
3. Firms are grouped by risk "clusters" or buckets, as a function of their free cash flow volatility and time-to-maturity in each period (see section 3.3.1);
4. Credit risk is assessed for each company and future cash flows to debt holders are forecasted taking into account the impact of future defaults and restructuring scenarios (see section 3.3);
5. Observed market prices (spreads) in each year are used to estimate spreads as a function of observable characteristics of firms, such as risk cluster, duration, cash flow volatility, and the estimated relation between spreads and firm characteristics is then used to obtain a mark-to-market price for each firm in that year, given each firm's own characteristics (see section 3.3.3);
6. Finally, after individual performance metrics have been obtained for each firm's senior debt, a return covariance matrix is estimated for each reference portfolio or index (and subindex) and individual assets are aggregated following certain inclusion and rebalancing rules (see sections 3.4.1 and 3.4.2).

Three Key Indices

The three indices described below cover the 2000-2016 period and are defined thus:

1. A **broad market infrastructure debt index**, covering 14 European countries and six industrial sector groups, includes 216 "live" borrowers of infrastructure debt in 2016, or 867 senior debt instruments, with a capitalisation of EUR106.1bn. Over the period, 298 borrowers are included in the index, representing 1,089 individual debt instruments;
2. A **private infrastructure project debt index** for the same geography including 160 live borrowers in 2016 for a capitalisation of EUR48.7Bn, or 415 instruments. This index has included as many as 219 borrowers, representing as many as 544 senior debt instruments;
3. An **infrastructure corporate debt index** also covering Europe, with a EUR57.4Bn capitalisation in 2016 for 56 live borrowers, corresponding to 447 senior debt instruments. Historically, the index has included as many as 79 borrowers representing 545 debt instruments.

Index constituents may have been removed from the "live" index because they have reached a maximum maturity or minimum time-to-maturity or size threshold, because the debt was prepaid, the borrower liquidated, or the debt sold following an event of restructuring. Events of debt refinancing or successful restructuring (workouts) lead to the creation of new instruments and the

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removal of the ones they replace from the index.

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

Figure 1 shows the composition of the broad market infrastructure debt index on a value-weighted basis.

Infrastructure Debt Is Unique

The following stylised facts about the risk-adjusted performance of private infrastructure debt can be drawn from our results.

The broad European market infrastructure debt index (including project and infrastructure corporate debt)...

1. ...significantly outperforms the European corporate bond debt index over the 2000-2016 period, thanks to a significant yield spread;
2. On a value-weighted basis, the broad market infrastructure debt index exhibits significant concentration, and its Sharpe ratio or risk-adjusted performance is not significantly different from that of the corporate bond index;
3. However, the broad market infrastructure debt index exhibits higher risk-adjusted performance on an equally weighted basis when its level of concentration is equivalent to that of the corporate bond index;
4. The duration and value-at-risk of our broad market index are higher than the public senior corporate bond reference index, justifying higher returns but also exhibiting converging tendencies over the period.

The European broad market senior infrastructure index clearly behaves differently than its senior corporate bond comparator, but the difference on a risk-adjusted basis is not always very "clean." Examining the behaviour of the two subindices that make up this broad-market measure allows a more granular understanding.

But Project Finance and Infrastructure Corporate Debt Are Different

The infrastructure project finance senior debt index...

1. ...does not deliver a better cumulative outperformance than the broad market infrastructure debt index over the entire period;
2. Still, its yield spread is higher than the broad infrastructure debt market's after 2006, and project finance debt has been the best performer at the 10-year horizon or lower by a substantial margin;
3. On a risk-adjusted basis, for either value- or equally weighted portfolios, project finance debt improves on the corporate bond index by 30-60 basis points (per unit of risk) at different horizons;
4. Duration and value-at-risk are consistently higher than the corporate debt

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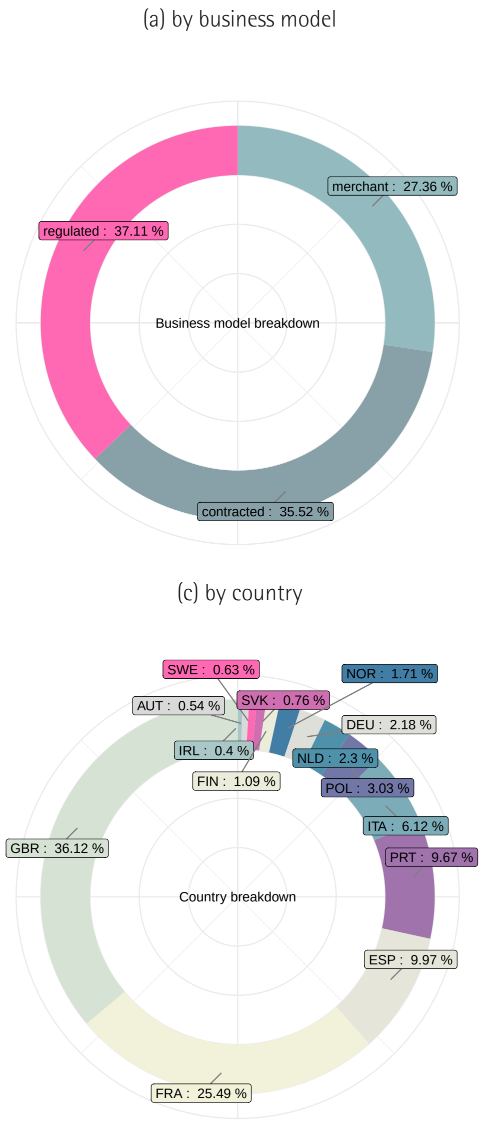
Figure 1: EDHEC*infra* **broad market** infrastructure debt index, **value weighted**, 2016 breakdown by market value



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index by a relatively small and decreasing margin over the period;
5. In terms of return volatility, the project finance debt index has the lowest risk profile.

Finally, the infrastructure corporates senior debt index...

1. ...delivers a better cumulative performance than corporate bonds or project finance debt over the 16-year period primarily due to higher returns in earlier years;
2. After 2006 its yield spread is much lower than that of project finance debt, even though it bounces back in 2013;
3. Critically, on a risk-adjusted basis, even looking at the more diversified equally weighted index, infrastructure corporates fails to deliver a Sharpe ratio that improves on that of the listed corporate bond reference index, that is, infrastructure corporate debt may have higher returns but it also is much more volatile both than corporate bonds and project finance debt;
4. European infrastructure corporates have the highest value-at-risk of the different indices considered.

Table 1 provides an overview of these findings.

We conclude that while infrastructure project finance debt has a unique risk-reward profile, infrastructure corporates probably cannot qualify as a new asset class. With a Sharpe ratio that cannot be distinguished from that of the public senior corporate bond market reference, infrastructure corporates are a higher-risk/higher-return subset of the senior corporate bond bucket.

In conclusion, looking at 16 years of data for 14 European countries, a private infrastructure senior debt index exhibits investment characteristics that set it clearly apart from a senior corporate debt index. However, this broad market infrastructure debt index is composed of two subgroups of assets that have different profiles: the first one, infrastructure project finance, has a unique risk/reward profile and offers a relatively high reward per unit of risk, especially since 2007; the second one, infrastructure corporate debt, is a higher-risk/higher-return version of the corporate debt market, but it does not offer a better level of risk-adjusted performance than corporate debt.

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Table 1: Infrastructure debt indices key metrics, broad market, senior project, and corporate infrastructure debt, Europe(14), fully hedged

A) Broad Market

A1) Value-Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	3.83%	4.91%	6.72%	6.8%	8.31%
Volatility	4.52%	4.34%	4.29%	4.32%	5.67%
Sharpe Ratio	1.26	1.5	1.9	1.7	1.56
Max Drawdown	0%	0%	0%	0%	0%

A2) Equally Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	4.39%	5.48%	7.12%	6.95%	8.11%
Volatility	3.65%	3.56%	3.51%	3.49%	3.73%
Sharpe Ratio	1.71	1.98	2.43	2.14	2.17
Max Drawdown	0%	0%	0%	0%	0%

B) Infrastructure Project Debt

B1) Value-Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	4.78%	6.25%	8.13%	7.76%	8.26%
Volatility	3.9%	3.78%	3.67%	3.7%	4.09%
Sharpe Ratio	1.7	2.07	2.61	2.25	2.06
Max Drawdown	0%	0%	0%	0%	0%

B2) Equally Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	4.64%	5.83%	7.44%	7.07%	7.95%
Volatility	3.48%	3.39%	3.31%	3.32%	3.66%
Sharpe Ratio	1.86	2.19	2.68	2.3	2.19
Max Drawdown	0%	0%	0%	0%	0%

C) Corporate Infrastructure Debt

C1) Value-Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	3.07%	3.93%	5.71%	6.15%	8.19%
Volatility	5.67%	5.24%	5.11%	5.05%	7.22%
Sharpe Ratio	0.87	1.06	1.4	1.32	1.25
Max Drawdown	0%	0%	0%	0%	0%

C2) Equally Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	3.69%	4.57%	6.27%	6.62%	8.45%
Volatility	4.36%	4.15%	4.1%	4%	4.61%
Sharpe Ratio	1.27	1.48	1.87	1.78	1.84
Max Drawdown	0%	0%	0%	0%	0%

D) Public Corporate Market Index Reference (value-weighted)

	1-year	3-year	5-year	10-year	Hist
Return	2.78%	3.48%	5.26%	4.75%	5.2%
Volatility	3.18%	2.65%	2.79%	3.16%	2.94%
Sharpe Ratio	1.46	1.9	2.37	1.67	1.77
Max Drawdown	0%	0%	0%	1.51%	1.51%

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. Max Drawdown is the maximum peak to trough in value over the reference period. The listed corporate debt index reference is the iBoxx Senior European Corporate Debt Index, value weighted. All market-reference metrics are computed using raw iBoxx data and the same methodologies used for the infrastructure indices.

1. Introduction

1. Introduction

In this paper, we present the first results of a multiyear project to create and compute fully fledged private infrastructure debt 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 family of credit instruments that have become of increasing interest to institutional investors.

Investors may look to private infrastructure debt in search of yield, diversification, or duration-hedging instruments, but they have until now been unable to fully validate any intuitions about this type of private debt.

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 debt benchmarks is a prime example of applied academic research designed to have an impact on real-world business practices 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 levels.

The first version of these indices spans 14 European countries over 16 years, going back to 2000. These indices are built from a representative sample by size and vintage of the private European infrastructure debt market, including hundreds of borrowers and debt instruments over that period.

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

1. The first one equates infrastructure investment with "project finance" [4] and echoes the June 2016 advice of the European insurance regulator (EIOPA, 2016) to the European Commission to define "qualifying infrastructure" for the purposes of the Solvency-II directive;
2. The second view, also expressed during recent prudential regulatory consultations, defines infrastructure investment more broadly and proposes to include "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.

In other words, it can be argued that the investment characteristics of "private infrastructure debt" are derived from the specific corporate governance structure

4 - i.e., the debt instruments used to finance project-specific firms that are expected to operate within very strict constraints over the life of a single investment project (e.g., a toll road or a power plant).

1. Introduction

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.).

In this paper, we use the EDHEC*infra* database and technology to address two simple questions:

1. How does a "broad market" index of private infrastructure senior debt perform against an equivalent corporate senior debt index?
2. Is there a difference between the risk-adjusted performance of infrastructure "project finance" debt and that of "infrastructure corporates," and to what extent do these two subindices contribute to the performance of a broad market infrastructure debt index?

Answering these two questions is instrumental to establishing the existence of an "infrastructure debt asset class," both from an asset-allocation and a prudential perspective, and to defining which types of instruments should qualify for a potential new bucket or prudential risk charge.

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 and instrument-level data. Section 3 summarises the methods used to compute the indices, from cash flow models to asset pricing to portfolio construction. Section 4 presents the results for three major private infrastructure debt indices: a broad market index, an infrastructure project debt index, and an "infrastructure corporates" debt index. 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 their private debt and to select a representative sample of these instruments to be included in a "broad market" private infrastructure debt index for Europe.

Research using private data often suffers from multiple biases created by the source of data. To avoid this problem, when selecting constituents and collecting data, we take a "bottom-up" approach to identifying individual firms and instruments and to collecting the relevant data from a range of public and private sources. Thus, we avoid creating biases in the data collection by overweighting data made available by any one contributor, a common problem with studies involving privately sourced data. Here, the relevant firms and debt instruments are identified first, and in a second step, the relevant data is collected for a representative sample of the investable universe for which data can be collected.

2.1 Investable Universe and Market Sample

2.1.1 Coverage

The private infrastructure debt universe under consideration is a subset of the investable infrastructure market in 14 European countries.

In each national market, "investable infrastructure companies" are identified. These are either the special-purpose entities typically used in infrastructure-project financing, or a limited number of "pure" regulated or merchant infrastructure businesses such as ports, airports, or water companies. The latter are selected only if the majority of their commercial activity is related to providing certain infrastructure services in a narrow sense.[5] 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 1990s depending on the country, we identify a population of 2,687 private infrastructure companies that has, at one point, been investable. Not all these firms are investable as of 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.

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).

Coverage is computed on the basis of a population in which individual firms and projects are included if we can observe at least their incorporation and investment start (or financial close) dates, country, sector, and business model categories, as well as corporate structure (SPV or

5 - Multi-utilities and infrastructure conglomerates are excluded.

2. Universe and Data

"corporate") and sufficient information about total assets (book value) and outstanding senior debt.

Next, 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).

The left panel of figure 2 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-grey dots, while the pink line indicates the share of total value in the investable universe tracked by the sample.

Figure 2 highlights the evolution of the investable infrastructure market in Europe over the period. A decade and a half ago, fewer private investment opportunities existed in Europe and they were, on average, 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.

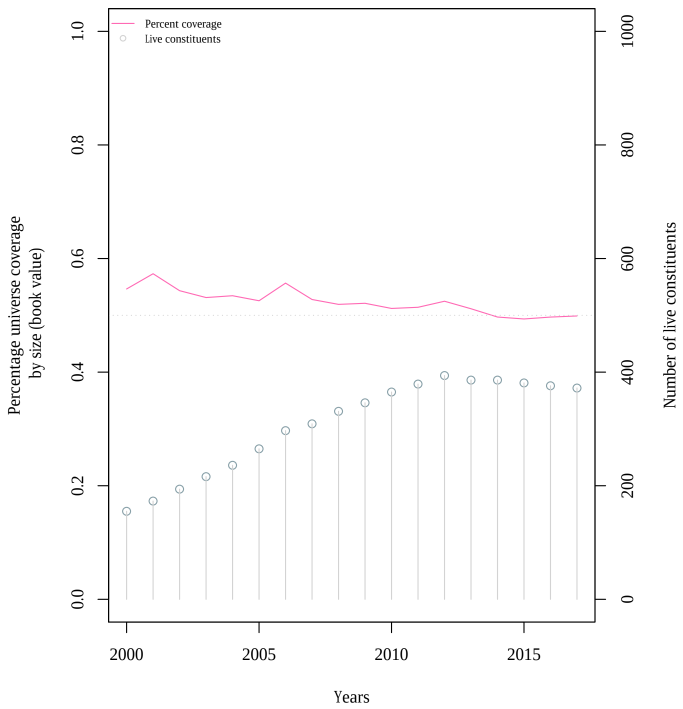
As a result, our index sample in 2000 includes 155 firms and 121 senior debt investments, representing 54.6% of the investable firm universe and close to 80% of the investable debt universe at the time by total book value. It peaks in 2012 at 394 firms, or 52.4% of the universe, and 309 senior debt constituents, or 56.4% of the market.

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. 243 such firms still have live outstanding senior debt while 87 have fully repaid, prepaid, or failed to repay third party credit.

Of the investable infrastructure market identified, not all firms have outstanding senior debt provided by third party creditors (as opposed to the firm's shareholders). Among the 400 firms identified, 330 are found to have senior term debt provided by commercial banks, private loan investors, or bond holders.

2. Universe and Data

Figure 2: Universe coverage of market sample



2.1.2 Private Infrastructure Debt Universe Breakdown

A 2016 snapshot of the infrastructure debt market sample, broken down by number of firms, is given in figures 3, 4, and 5 for country, sector, and corporate structure categories, respectively. Similar breakdowns by market value are available for individual indices and described in the appendix for the three indices discussed in section 4.

2.2 Data Collection

2.2.1 Infrastructure Firm Data

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*,[6] firms and instruments also have individual *attributes*,[7] and they are also attached to *values* (see Blanc-Brude et al., 2016, for a detailed discussion).[8]

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

Two issues impact the collection of debt instrument data:

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

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

8 - 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.

2. Universe and Data

Figure 3: Index sample country breakdown

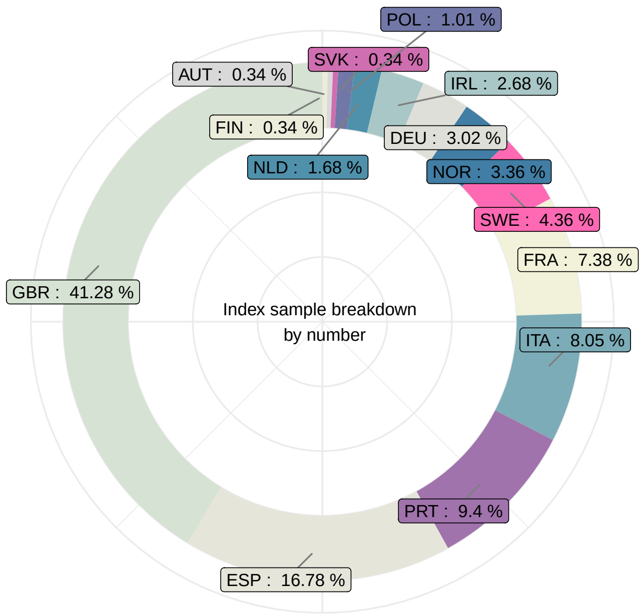
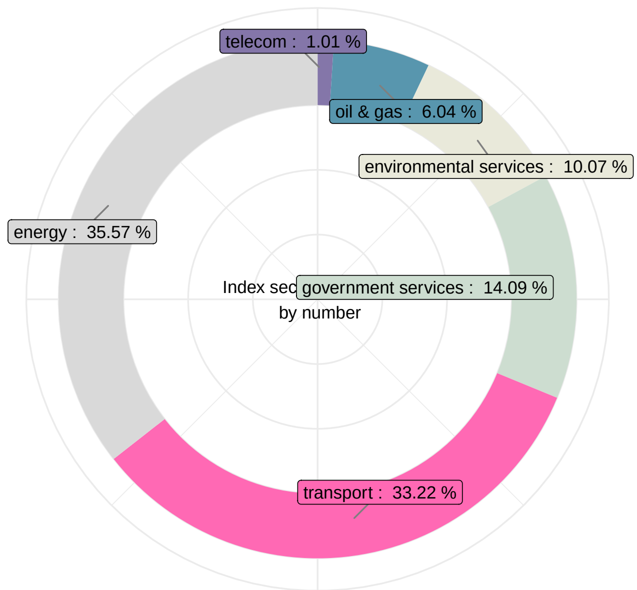
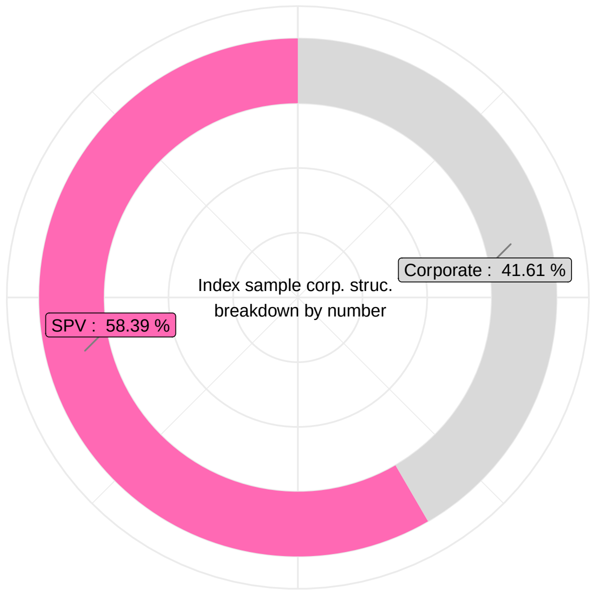


Figure 4: Index sample sector coverage breakdown



2. Universe and Data

Figure 5: Index sample corporate structure breakdown



- The source of issuance has to be clearly identified. Three major debt issuing structures can issue private infrastructure debt: the infrastructure asset owner, a related finance company, and a parent as part of portfolio financing. The latter was mainly observed when a company held several infrastructure projects of a similar type (e.g. power stations or wind farms). Identification of the debt instruments solely associated with the infrastructure asset being researched was necessary before data collection could proceed. Multiple reference sources were consulted to ensure that the debt data was as fully described as possible;
- Subsequent corporate actions also have a profound effect on the outstanding debt balance for each infrastructure asset. Following the takeover of an infrastructure SPV's holding company, project-level debt can be repaid early and replaced by parent-company financing. Furthermore, infrastructure portfolio companies can issue more debt to add more assets to their portfolios. These changes in the debt outstanding of the infrastructure firms, as well the usual observations of debt refinancing, have to be logged every year.

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.

Data sources used include annual audited accounts filed with the relevant regulators in each country; contributed data from asset managers, asset owners, and commercial and other lenders; freedom of information requests; and commercial and open-access

2. Universe and Data

databases of infrastructure projects, project finance, and mergers and acquisitions[9]. The physical and spatial characteristics of each infrastructure are also collected from Open Street Map and various open source GIS databases, and can be used to map the constituents of different subindices.

9 - including Infratsructure Journal, Dealogic, Preqin, Infrastructure Investor and Thomson Banker.

2.2.2 Market Benchmark Data

Raw market data used to measure risk-free rates and the listed corporate debt refercen index are sourced from Datastream and Markit. In the next section, we describe the methodologies used to model the cash flows of each firm and instrument in the index sample before applying a structural credit-risk and asset-valuation model to each senior debt tranche 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 debt is seldom traded, and only a limited amount of market-price data is observable. Hence, the risk-adjusted performance of the senior debt of each firm in the index sample is derived by forecasting cash flows to debt holders, taking into account future scenarios of default and restructuring, and discounting them according to duration and volatility of future payouts and prevailing market conditions, using discount rates inferred from observed market prices (including the initial value of the investment and comparable transactions taking place each year).

Once each senior debt tranche 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. The latest "base case" senior debt service (i.e., future principal and debt repayments) is either obtained from data contributors or estimated using information available about each senior debt instrument present in the firm's capital structure (section 3.2.1);
2. The mean and variance of the firm's debt service cover ratio (DSCR) are estimated for each firm in all realised periods and forecasted for the remainder of the firm's debt maturity (section 3.2.2);
3. Firms are grouped by risk "clusters" or buckets, as a function of their free cash flow volatility and time-to-maturity in each period (section 3.3.1);
4. Credit risk is assessed for each company and future cash flows to debt holders are forecasted taking into account the impact of future defaults and restructuring scenarios (section 3.3);
5. Observed market prices (spreads) in each year are used to estimate spreads as a function of observable characteristics of firms, such as risk cluster, duration, cash flow volatility, and the estimated relation between spreads and firm characteristics is then used to obtain a mark-to-market price for each firm in that year, given each firm's own characteristics (section 3.3.3);
6. Finally, after individual performance metrics have been obtained for each firm's senior debt, a return covariance matrix is estimated for each portfolio or index (and subindex) and individual assets are aggregated following certain inclusion and rebalancing rules (see section 3.4.1 and 3.4.2 below).

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3.2 Cash Flows

Blanc-Brude et al. (2014) have shown that knowing the current or "base case" senior debt service of the firm, as well as the statistical characteristics (mean and variance) of the debt service cover ratio of private firms is sufficient to implement a proper structural credit risk model. In sections 3.2.1 and 3.2.2, we summarise the approach taken to obtain these two inputs for each firm in the index sample.

3.2.1 Current Debt Service

The future senior debt service currently owed by each firm in the index sample is obtained from one of the following sources:

1. Private contributor data or bond documentation; or
2. Computation using individual debt instruments' attributes (outstanding principal, interest rate, maturity date, and amortisation profile) collected from contributors or audited accounts; or
3. Estimation using Bayesian inference after 4 or 5 years of observed principal and interest payments, and other available information about the firm in question (e.g., average "tail" length [10]) and similar firms, as well as upper and lower bounds on credit spreads and yield-to-maturity at the time of origination (estimated from market data), typical amortisation profiles used in similar transactions, etc. (see Hasan and Blanc-Brude, 2017a, for more details)

10 - Loan tail in project finance: the number of years beyond loan maturity during which the project is still operational.

Using these simple techniques, the future total senior debt service (principal and interest) owed by each firm in the index sample is known with reasonable certainty at the time of computing the index and can be re-estimated on a regular basis, as new information about the firm's financial structure becomes apparent (e.g., refinancings, restructuring post default, etc.).

3.2.2 DSCR Mean and Volatility

Debt service cover ratios, or DSCRs, provide an economically significant measure of the ability of a firm to service its debt. At each point in time, the $DSCR_t$ is defined as:

$$DSCR_t = \frac{CFADS_t}{DS_t}$$

where DS_t is the senior debt service owned at time t and $CFADS_t$ is the cash flow available for debt service (the free cash flow) at time t.

For this index, an "economic" or cash-based $DSCR_t$ is computed for each firm in the index sample, using cash flow statement information, so that:

$$DSCR_t = \frac{\mathrm{C_{bank}} + \mathrm{C_{op}} + \mathrm{C_{IA}} + \mathrm{C_{dd}} - \mathrm{C_{inv}}}{\mathrm{DS_{senior}}}$$

where $\mathrm{C_{bank}}$, $\mathrm{C_{op}}$, $\mathrm{C_{IA}}$, $\mathrm{C_{dd}}$, and $\mathrm{C_{inv}}$ denote cash at bank, cash from operating activities, cash withdrawal from investment accounts, cash from debt drawdowns, and cash invested in physical investments, respectively (see Blanc-Brude et al., 2016, for a more detailed discussion of how DSCRs can be computed).

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

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DSCR state estimation

In a first step, the mean μ and variance σ^2 parameters (or state) of the DSCR 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 DSCR 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 DSCR process in each period, based on an initial guess (or prior) and an autoregressive model expressing a firm's ability to pay its debt in any given year as a function of its ability to do so in the previous year and of the effect of various control variables (e.g. time-to-maturity, future debt service profile, 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 DSCR observation at time t, f_t is the "evolution" function, and g_t is the vector containing relevant control inputs. ε_t and η_t are two independent white noise sequences with mean zero and variance σ^2 and ω^2 respectively, which are the unknown parameters.

With each DSCR observation, the true value of the mean and variance parameters of each firm's DSCR 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 DSCR process in the (μ, σ^2) plane.

Figures 6 and 7 illustrate this process for two example project companies in Italy and Germany: the time t value of the DSCR mean and variance is predicted at time $t-1$ and effectively tracks the realised DSCR value at time t.

DSCR forecasting

Once the parameters of the DSCR 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 DSCR until the maturity date of the current senior debt.

This is achieved by implementing Kalman filtering techniques with recursively computed "innovations" of the DSCR process as described in Wang and Blanc-Brude (2017) and illustrated in figure 7.

In view of the Markovian (autoregressive) nature of the state space model, the recursive formulae of the mean and variance of the firm's DSCR at a future time $t+k$, given the observed data up to time t, are also derived using Bayesian methods: the μ_t and σ_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.

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Figure 6: Estimated DSCR mean and variance trajectory in time

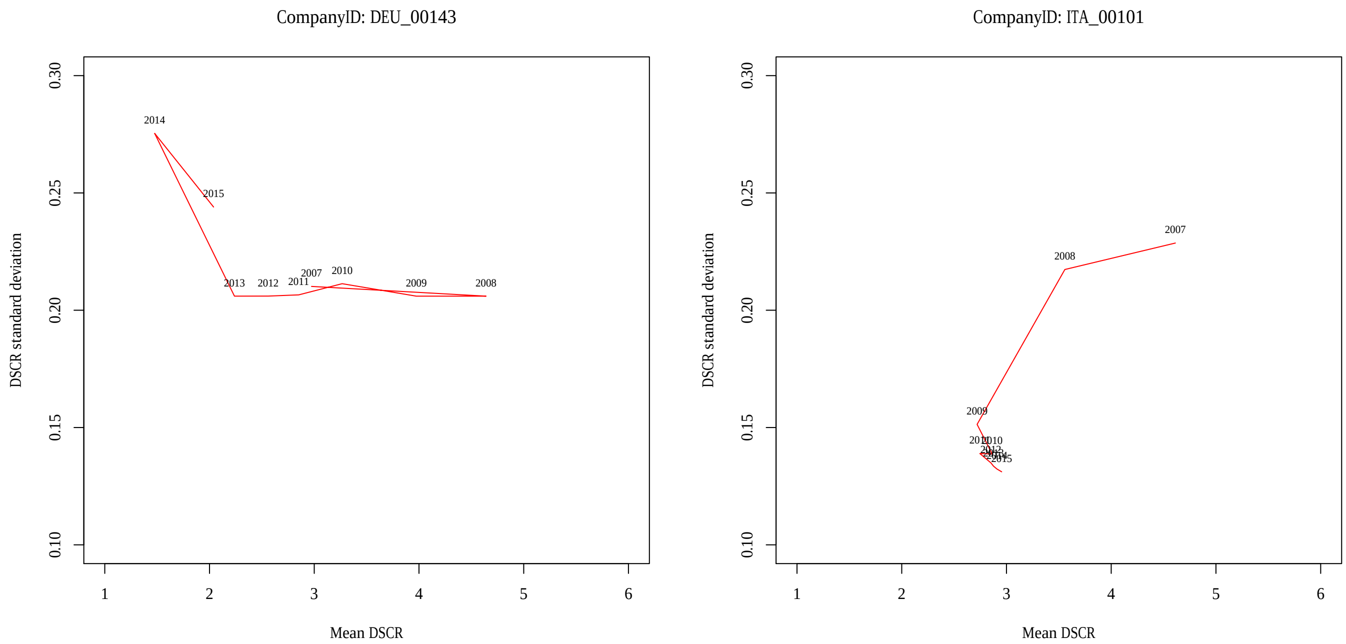
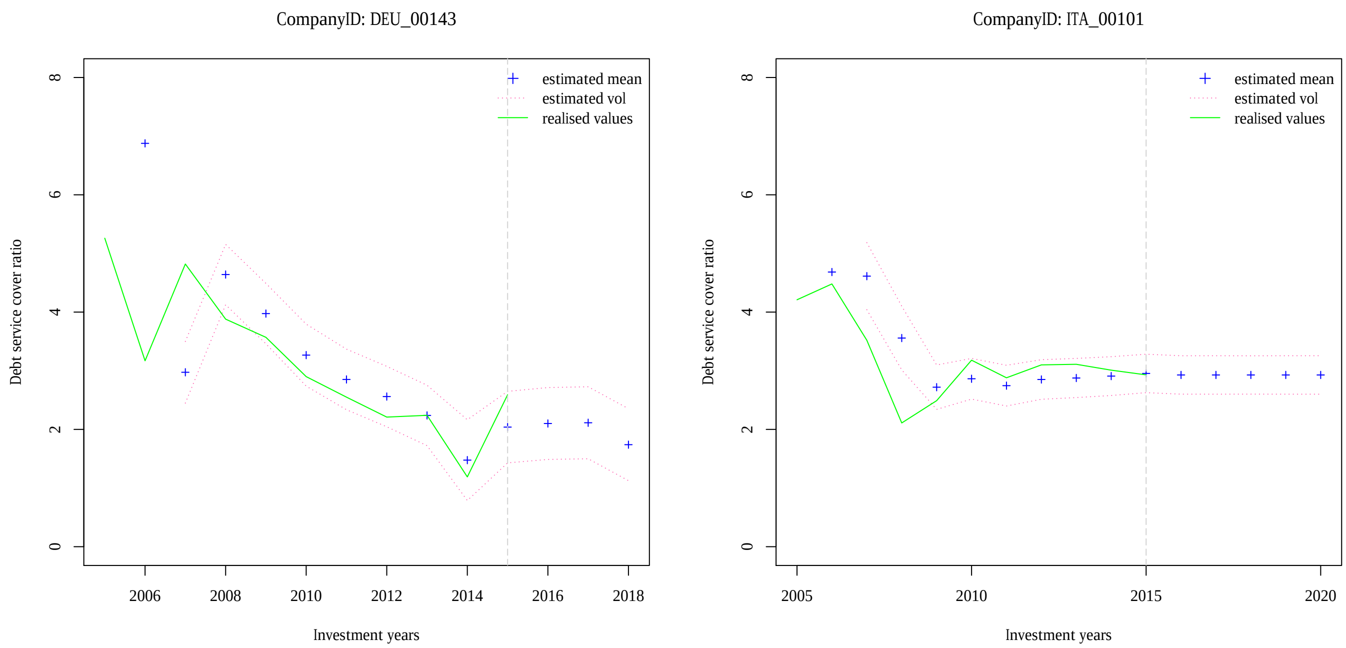


Figure 7: Estimated and forecast DSCR mean and variance in time



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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 μ and σ^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.

3.3 Asset Pricing

3.3.1 Risk Buckets

Next, once a DSCR 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 variance of $DSCR_t$), 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' senior debt 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 previous ones 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

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).

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consists of the two groups with the smallest intergroup dissimilarity. The number of final groups depends on the heterogeneity of the original data.

Figure 8 illustrates this process: firms from all three infrastructure business models (contracted, merchant, and regulated) can somewhat overlap in terms of DSCR variance, and for the purpose of asset pricing, much more homogenous risk groupings can be made using hierarchical clustering.

3.3.2 Credit Risk

Once the current senior debt service is known until the maturity of each instrument and the characteristics of the DSCR stochastic process are estimated and forecasted for the remaining of each firm's senior debt life, the private debt asset pricing framework described in Blanc-Brude and Hasan (2016) and Hasan and Blanc-Brude (2017c) – which we refer to as the BBH framework – can readily be applied.

BBH show that a fully fledged, cash flow driven structural credit risk model could be applied to infrastructure project debt since the *distance to default* (DD) metric at the heart of the Merton (1974) model can be written:

$$DD_t = \frac{1}{\sigma_{DSCR_t}} \frac{\mathrm{DS}^{\mathrm{BC}}_{t-1}}{\mathrm{DS}^{\mathrm{BC}}_t} (1 - \frac{1}{DSCR_t})$$

and the $DSCR_t$ metric itself provides an unambiguous definition of the various default thresholds that are relevant to predicting default accurately.

BBH also build on the fact that the free cash flow of the firms can be written as:

$$\mathrm{CFADS}_t = \mathrm{DSCR}_t \times \mathrm{DS}^{\mathrm{BC}}_t$$

to argue that in the case of infrastructure investment, because the value of the firm is solely driven by the value of future free cash flows,[12] knowledge of the $DSCR_t$ process and of the current debt service DS_t is sufficient to value the entire firm and build a stochastic model of the cash flow waterfall.

The value of senior debt is then the discounted value of expected cash flows to senior debt holders, taking into account the different path that such cash flows might take under different DSCR scenarios. BBH adapt the Black and Cox (1976) extension of the Merton model to express the value of the firm as the combination of all possible paths given a set of estimated $DSCR_t$ dynamics, as discussed in section 3.2.2).

Scenarios under which the $DSCR_t$ process would breach either a technical or hard default threshold are incorporated using a game theoretical renegotiation model of the restructuring of senior debt, balancing the relative bargaining power of debt and equity holders (see Hasan and Blanc-Brude, 2017c, for more details). Depending on the corporate structure of the firm (project finance SPV or corporation) different assumptions can be made about the relevant level of default thresholds and renegotiation/restructuring costs).

Hence, the BBH framework allows taking into account the "option value of the debt

12 - The capital investment is sunk and relationship-specific, i.e., it has no alternative use and is often *de jure* part of the public domain.

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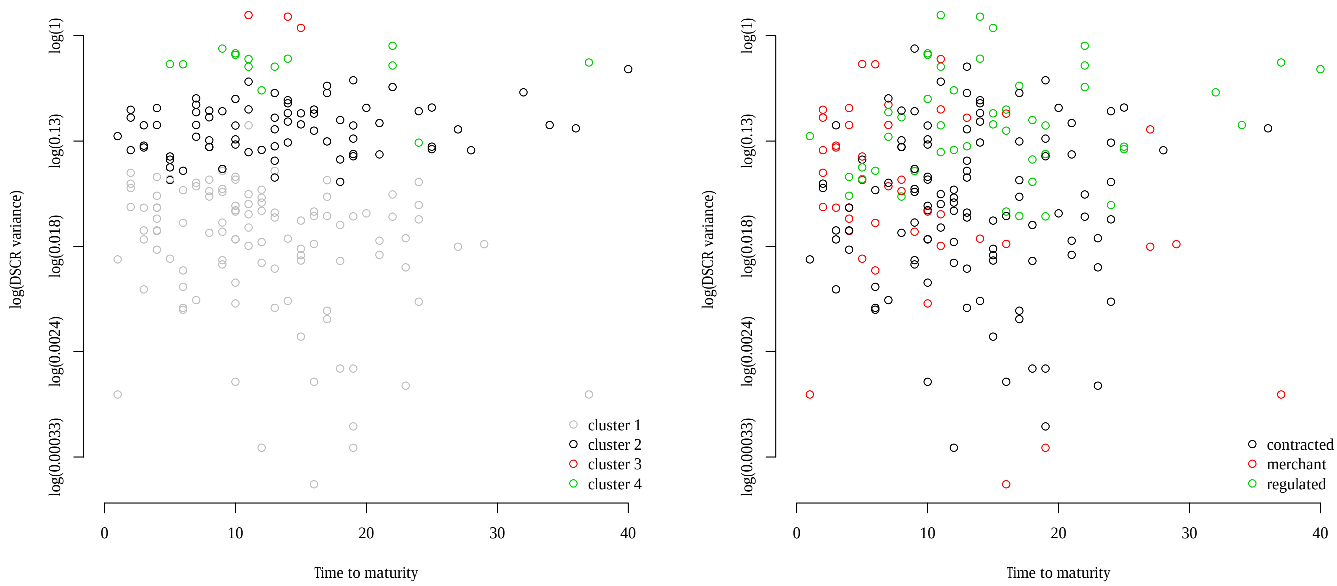
Figure 8: Hierarchical cluster and business model groupings of infrastructure borrowers in the DSCR variance and time-to-maturity plane



tail" found in infrastructure project finance, that is, the embedded option for lenders to either waive default events or walk away from or work out (restructure) the problem in order to maximise the expected value (or minimise the expected loss) of their investment.

This framework also allows predicting defaults and computing expected recovery rates at the firm level, avoiding the use of sector or regional averages for credit metrics, which can be poor approximations of the credit risk of individual exposures. For instance, in our index sample, certain firms exhibit DSCR levels that are either sufficiently high or of low enough volatility to be assigned expected default frequencies equal to zero. Importantly, these characteristics change over time and need to be tracked at the firm level as shown above. Hence, other firms which are, on average, considered to be low risk, such as "availability payment" public-private partnerships, can exhibit increasingly volatile or decreasing DSCRs, implying an increasing probability of default.

3.3.3 Discount Factors

The original BBH framework uses the standard risk-neutral valuation framework, assuming a required price of risk (Sharpe ratio) for specific lenders/investors (see also Kealhofer, 2003).

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 firm's senior debt

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cash flows. 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).

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:

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

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 τ-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 τ-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 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, senior infrastructure debt 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, forecast cash flows, and conditional payout volatility.

Since the only asset-specific term in the price of risk is the asset correlation with the

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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.

The "risk 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 spread 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 spread 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, 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 estimating the extent to which different risk exposures are priced. Performing this procedure year by year using instruments originated in each year, allows inferring 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 DSCR 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 debt.

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 (2017b).

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3.4 Portfolio Construction

Thus, a combination of cash flow, clustering, and asset-pricing models allows estimating the full range of performance metrics required for investment benchmarking at the asset level: single-period rates of return, volatility of returns, Sharpe and Sortino ratios, 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 (a.k.a. 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 to unity), and Σ, the variance-covariance matrix of the portfolio returns.

When estimating Σ the main challenge is 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 pair-wise covariance results in some estimation error and the multiplication of the 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 debt are what we set out to discover and cannot be assumed *ex ante*. 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 intra-cluster covariances and estimated in any given year for the main index or any subindex of private infrastructure debt.

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.

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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, as described in section 2.

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 most indebted issuers and increases risk and issuer concentration. This could be a particular concern in the case of a broad market infrastructure debt index, since very large corporate issuers (utilities) are found side by side with relatively small project finance SPVs, the impact of which on the index is dwarfed by the largest issuers.

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 infrastructure debt.

In the context of traditional and liquid fixed-income and equity indices, index weighting schemes are associated with rebalancing decisions requiring buying/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 debt cannot easily or speedily adjust their ownership of the senior debt of any given firm.

Here, on a value-weight basis, each exposure is considered to represent the whole stock of senior debt 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 debt instruments.

In this sense, rebalancing only happens at the issuer selection stage, that is, when building a representative portfolio of the identified investable universe, and each time 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.[13]

Three simple portfolio-inclusion rules are implemented to avoid unnecessary noise/distortion of reported performance:[14]

- A minimum outstanding maturity of two years;
- A minimum outstanding face value of one million euros;
- A maximum outstanding maturity of 30 years.

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

14 - These rules permit avoiding extreme returns and volatility due to very low book or total senior debt outstanding values as a project approaches its maturity.

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In the next section, we present the resulting index-performance metrics, implementing the technology described above and using the data described in section 2, for three indices:

1. A broad market European debt index;
2. A European infrastructure project finance debt index;
3. A European infrastructure corporate Index.

4. Results

4. Results

The data and methodologies described in sections 2 and 3 allow creating indices focusing on specific geographies, sectors, business models, and corporate structures. There are 192 such indices of European infrastructure debt, in three investment currencies and on a "fully hedged" basis [15] available on the EDHEC*infra* website.

15 - 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 three main indices of the pan-European private infrastructure debt market (14 countries): a "broad market" index including both infrastructure "corporates" and projects or SPVs, and two subindices including only a single type of corporate structure.

This distinction is useful, among other reasons, because of the debate over the definition of "qualifying infrastructure" for different prudential regulatory frameworks [16] and whether both infrastructure projects' finance and "infrastructure corporates" should benefit from a specific prudential treatment.

16 - E.g., Solvency-II or the Basel-4/CRR2 treatment of "high quality" infrastructure debt.

More generally, the question of whether infrastructure debt is an asset class in its own right hinges partly around the distinction between different types of infrastructure borrowers and whether they fundamentally differ from other forms of private corporate debt instruments.

Since we are interested in the pure performance of portfolios of infrastructure debt instruments, in what follows we only report the performance of "fully hedged" indices.

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 of each index (4.1), their risk-adjusted performance (4.2), other risk metrics including credit risk (4.3), and a first discussion of performance attribution through factor decomposition (4.4).

4.1 Index Composition

The three indices described below cover the 2000-2016 period and are defined thus:

1. A **broad market infrastructure debt index**, covering 14 European countries and six industrial sector groups and including 216 "live" borrowers of infrastructure debt in 2016, or 867 senior debt instruments, with a capitalisation of EUR106.1bn. Over the period, 298 borrowers are included in the index, representing 1,089 individual debt instruments;
2. A **private infrastructure project debt index** for the same geography, including 160 live borrowers in 2016 for a capitalisation of EUR48.7Bn, or 415 instruments. [17] This index has included as many as 219 borrowers, representing as many as 544 senior debt instruments;
3. An **infrastructure corporate debt index** also covering Europe, with a EUR57.4Bn capitalisation in 2016 for 56 live borrowers, corresponding to 447

17 - As a point of reference, project finance origination in Europe tends to represent EUR70-100Bn of new credit instruments each year (Source: IJG).

4. Results

senior debt instruments. Historically, this index has included as many as 79 borrowers representing 545 debt instruments.

Index constituents may have been removed from the "live" index because they have reached a maximum maturity or minimum time-to-maturity or size threshold, because the debt was prepaid, the borrower liquidated, or the debt was sold following an event of restructuring. Events of debt refinancing or successful restructuring (workouts) lead to the creation of new instruments and the removal of the ones they replace from the index.

Each index is calculated on either a value-weighted or equally weighted basis. Next, we examine the type of constituents and the degree of concentration of each of the three indices.

4.1.1 Categories of Constituents

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

Figures 9 and 10 show the composition of the broad market infrastructure debt index, on a value-weighted and on an equally weighted basis, respectively.

Similar figures are available in the appendix for the Infrastructure Project Debt and Infrastructure Corporate Debt Indices.

A value-weighted infrastructure index tends to privilege larger types of infrastructure firms, including utilities and 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, a value-weighted basis 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.

Currency-wise, the index is mostly split between euro and sterling, representing the relative currency shares of the investable infrastructure sector in Europe today.

Conversely, an equally weighted index sees its 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 the equally weighted index.

Nevertheless, the UK and sterling retain equivalent weights in both equally weighted and value-weighted indices, highlighting the diversity and representativeness of the

4. Results

Figure 9: EDHEC*infra* **broad market** infrastructure debt index, **value weighted**, 2016 breakdown by market value

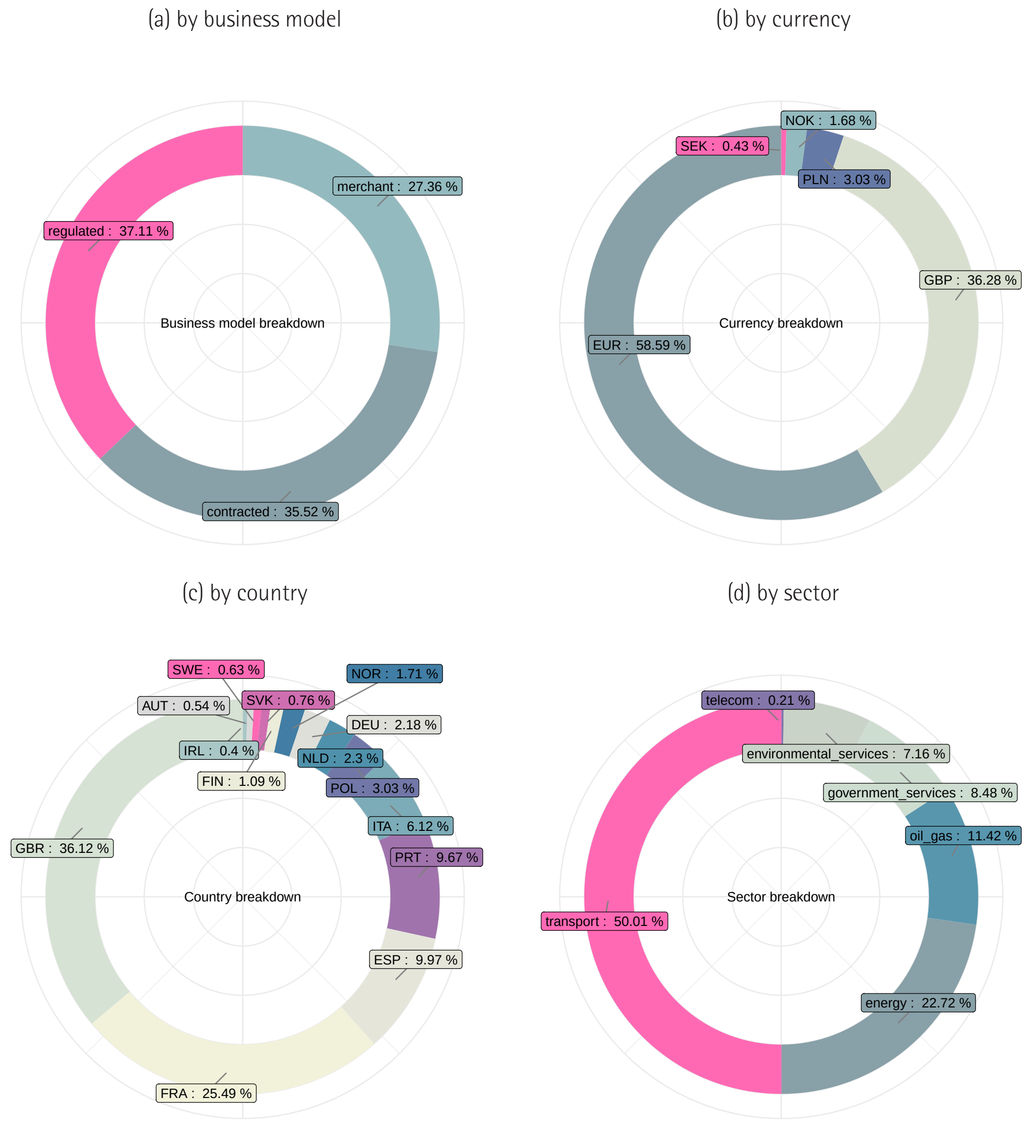

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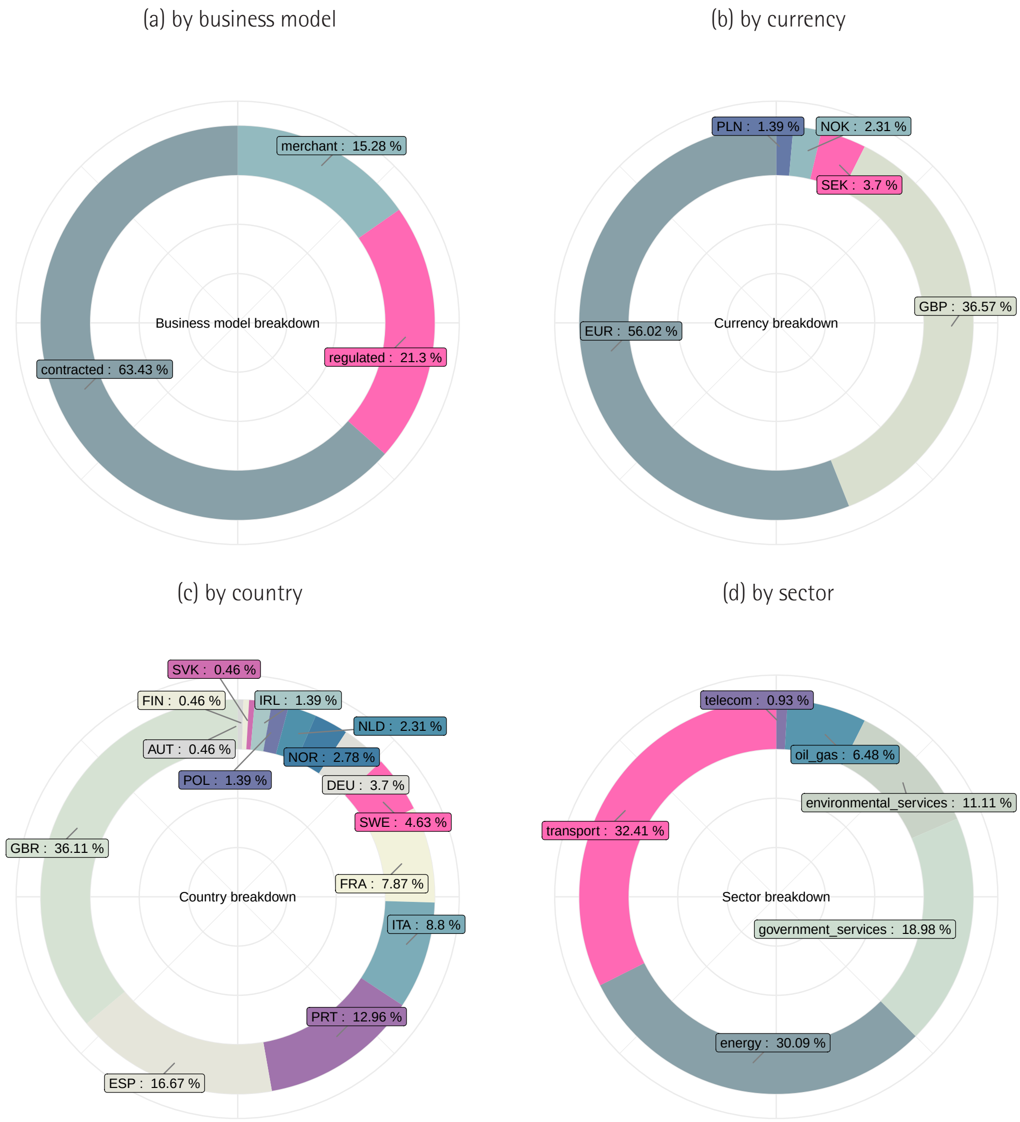
Figure 10: EDHEC*infra* **broad market** infrastructure debt index, **equally weighted**, 2016 breakdown by market value



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UK market when it comes to the structure of investable European infrastructure.

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

As a result, the weighting scheme of the index can also imply different levels of correlation with the rest of the economy or other asset classes. We return to the question of factor sensitivity in section 4.4.

The two 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.

Next we examine the degree of concentration of each index.

4.1.2 Concentration

Our infrastructure debt 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 debt market and the presence of high transaction costs would make these two strategies hard to replicate. Instead, these are two ideal-type portfolio weighting schemes, aiming to represent the "broad market" from two significant and relatively intuitive perspectives.

Table 2 compares the number of live index constituents in 2016 (number of eligible constituents) with the number of "effective constituents" or "effective number of bets" [18] explaining most of the performance of the index due to their larger weights.

It also shows the cumulative percentage of constituents necessary to reach 25 percent, 50 percent, etc. of the index-total capitalisation.

Panel A describes the concentration level of value-weighted indices, in comparison with the listed corporate debt reference index.

Clearly the value-weighted infrastructure indices are highly concentrated, even relative to the listed corporate debt reference index, which is also a value-weighted index.

Only 7 to 14% of constituents suffice to represent half of the value-weighted index capitalisation. In the case of infrastructure corporate debt, 13 effective bets can explain most of the performance.

In comparison, our equally weighted infrastructure debt indices have concentration profiles on par with the corporate debt reference index, as shown in panel B of figure 2.

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

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Table 2: Weight profiles: Broad market, project, and corporate infrastructure debt indices, Europe(14)

A) Value-Weighted Indices

Metrics	Brd Mkt Infra Debt	Infra Proj. Debt	Infra Corp. Debt	Corp. Debt Ref.
Effective Number of Constituents	38	61	13	1462
Number of Eligible Constituents	216	160	56	1781
Pct Constituents to 90pct Cap	46	51	43	83
Pct Constituents to 75pct Cap	25	32	23	60
Pct Constituents to 50pct Cap	8	14	7	33
Pct Constituents to 25pct Cap	1	4	2	13

B) Equally Weighted Indices*

Metrics	Brd Mkt Infra Debt	Infra Proj. Debt	Infra Corp. Debt	Corp. Debt Ref.
Effective Number of Constituents	216	160	56	1462
Number of Eligible Constituents	216	160	56	1781
Pct Constituents to 90pct Cap	90	90	89	83
Pct Constituents to 75pct Cap	75	75	73	60
Pct Constituents to 50pct Cap	50	50	48	33
Pct Constituents to 25pct Cap	25	25	23	13

The reference index is always value weighted.

Next, we examine the performance of each index relative to the listed corporate debt reference index.

4.2 Risk-Adjusted Performance

Table 3 shows key performance metrics for the three indices (Broad Market, Infrastructure Projects, and Infrastructure Corporates), compared with the iBoxx Senior Debt index for Europe, on a value-weighted and equally weighted basis.

All infrastructure and public reference indices exhibit a long-running downward trend in returns. We also note that the level of private infrastructure debt returns at different horizons is consistent with our anecdotal knowledge of the market cost of debt over the past two decades.

4.2.1 Broad Market Index

On a value-weighted basis, broad market senior infrastructure debt (panel A1) outperforms senior corporate debt (panel D) in Europe by a substantial margin, at each of the reported investment horizons: outperformance is approximately 300 bps historically, 200 bps at the 10-year horizon, and 150 bps at the 5-year horizon.

However, return volatility is also higher for the value-weighted broad market infrastructure debt index than for the listed corporate debt reference index. And as a result, the Sharpe ratio of the value-weighted broad market infrastructure debt index is lower than or equivalent to that of the listed corporate debt reference index at all horizons.

The annual maximum drawdown[19] of the value-weighted broad market infrastructure index is not different from zero. Indeed, fixed-income indices often exhibit zero annual drawdown except in very bad years. The infrastructure debt index thus seem more immune to drawdowns in very bad years, both on a value-weighted and equal-weighted basis. This characteristic is

19 - Maximum Drawdown is the maximum peak to trough in value over the reference period.

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Table 3: Infrastructure debt indices key metrics, broad market, senior project, and corporate infrastructure debt, Europe(14), fully hedged

A) Broad Market

A1) Value-Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	3.83%	4.91%	6.72%	6.8%	8.31%
Volatility	4.52%	4.34%	4.29%	4.32%	5.67%
Sharpe Ratio	1.26	1.5	1.9	1.7	1.56
Max Drawdown	0%	0%	0%	0%	0%

A2) Equally Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	4.39%	5.48%	7.12%	6.95%	8.11%
Volatility	3.65%	3.56%	3.51%	3.49%	3.73%
Sharpe Ratio	1.71	1.98	2.43	2.14	2.17
Max Drawdown	0%	0%	0%	0%	0%

B) Infrastructure Project Debt

B1) Value-Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	4.78%	6.25%	8.13%	7.76%	8.26%
Volatility	3.9%	3.78%	3.67%	3.7%	4.09%
Sharpe Ratio	1.7	2.07	2.61	2.25	2.06
Max Drawdown	0%	0%	0%	0%	0%

B2) Equally Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	4.64%	5.83%	7.44%	7.07%	7.95%
Volatility	3.48%	3.39%	3.31%	3.32%	3.66%
Sharpe Ratio	1.86	2.19	2.68	2.3	2.19
Max Drawdown	0%	0%	0%	0%	0%

C) Corporate Infrastructure Debt

C1) Value-Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	3.07%	3.93%	5.71%	6.15%	8.19%
Volatility	5.67%	5.24%	5.11%	5.05%	7.22%
Sharpe Ratio	0.87	1.06	1.4	1.32	1.25
Max Drawdown	0%	0%	0%	0%	0%

C2) Equally Weighted Index

	1-year	3-year	5-year	10-year	Hist
Return	3.69%	4.57%	6.27%	6.62%	8.45%
Volatility	4.36%	4.15%	4.1%	4%	4.61%
Sharpe Ratio	1.27	1.48	1.87	1.78	1.84
Max Drawdown	0%	0%	0%	0%	0%

D) Corporate Market Index Reference (value weighted)

	1-year	3-year	5-year	10-year	Hist
Return	2.78%	3.48%	5.26%	4.75%	5.2%
Volatility	3.18%	2.65%	2.79%	3.16%	2.94%
Sharpe Ratio	1.46	1.9	2.37	1.67	1.77
Max Drawdown	0%	0%	0%	1.51%	1.51%

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 listed corporate debt index reference is the iBoxx Senior European Corporate Debt Index, value weighted. All public market reference metrics are computed using raw iBoxx data and the same methodologies used for the infrastructure indices.

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confirmed when we look at annual returns and value-at-risk metrics below.

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

Looking at the equally weighted broad market infrastructure debt index (panel A2) thus provides a different perspective: outperformance relative to the public corporate debt reference index is equivalent or higher than in panel A1, but thanks to greater portfolio diversification, return volatility is now only marginally higher than that of the corporate debt index shown in panel D.

Hence, the Sharpe ratios of the equally weighted broad market infrastructure debt index are higher than the corporate debt reference index at all reported horizons: by 40 bps historically, 47 bps at the 10-year horizon, and 6 bps at the 5-year horizon.

Annual performance metrics for the broad market infrastructure debt index are shown in figures 11a and 11b. The index tends to perform better than the Corporate Debt Reference Index during the first half of the period until 2009. It is noticeable that when the market reference experiences zero or negative returns in the worst years, the infrastructure debt index stays in positive territory and significantly outperforms the listed market reference.

After 2009, the index outperforms the market less often but still exhibits strong countercyclical tendencies (e.g., 2013, 2015).

Figures 14 and 15 show the cumulative performance of infrastructure debt against the corporate debt reference index and confirm a very substantial outperformance. Due to higher returns in earlier years, the value-weighted index is the best performer on a historical basis.

Still, this latter index is highly concentrated and does not have a better Sharpe ratio than the public market reference. As is shown in figures 16 and 17, the value-weighted infrastructure index achieves a better Sharpe ratio than the listed corporate debt index reference only seven times out of 17 years, against 12 times for the equally weighted portfolios.

Hence, the value-weighted index has higher returns but also much higher risk than the equally weighted infrastructure debt index, and the level of risk found in the value-weighted index does not lead to an equivalent risk remuneration in the equally weighted index.

4.2.2 Project vs. Corporate Infrastructure Debt

We turn to the two subparts of the broad market infrastructure debt index, infrastructure project finance debt (panel B) and infrastructure corporate debt (panel C) in table 3, to better understand the performance of the broad market index and what

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Figure 11: Annual performance: EDHEC*infra* **broad market** private infrastructure debt index, Europe(14), 2000-2016

(a) value weighted (b) equally weighted

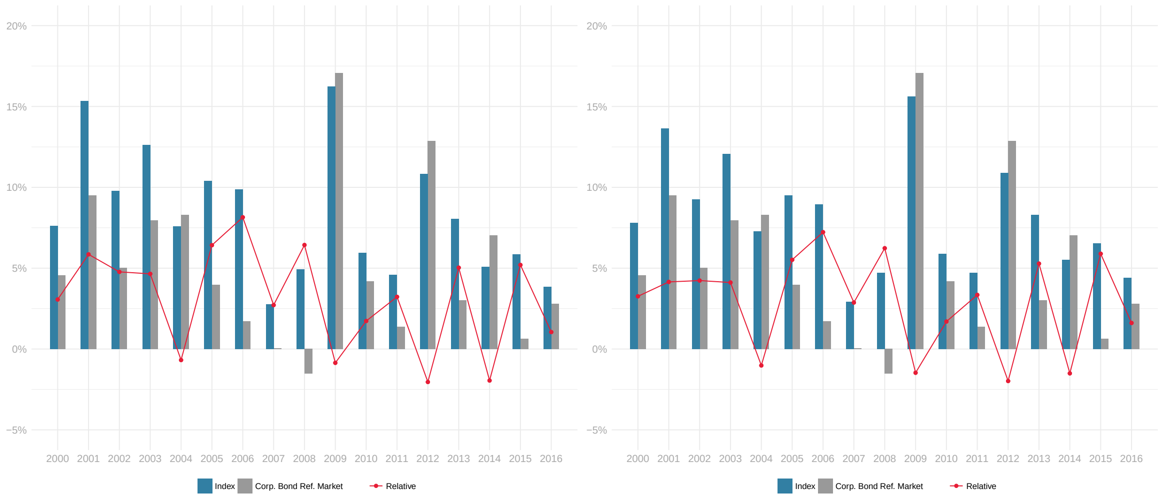

Figure 12: Annual performance: EDHEC*infra* private infrastructure **project debt** index, Europe(14), 2000-2016

(a) value weighted (b) equally weighted

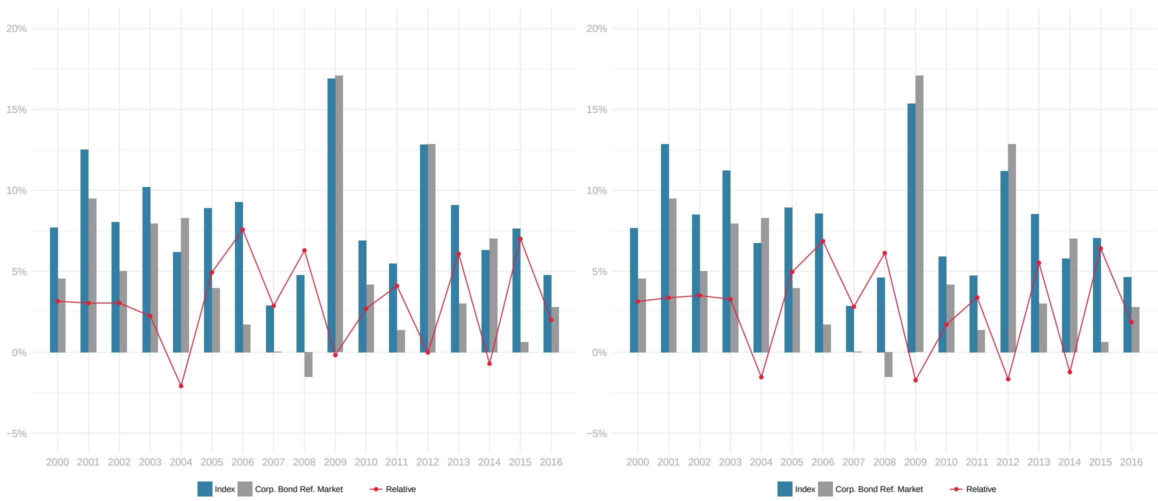

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Figure 13: Annual performance: EDHEC*infra* **infrastructure corporates** debt index, Europe(14), 2000-2016

(a) value weighted

(b) equally weighted

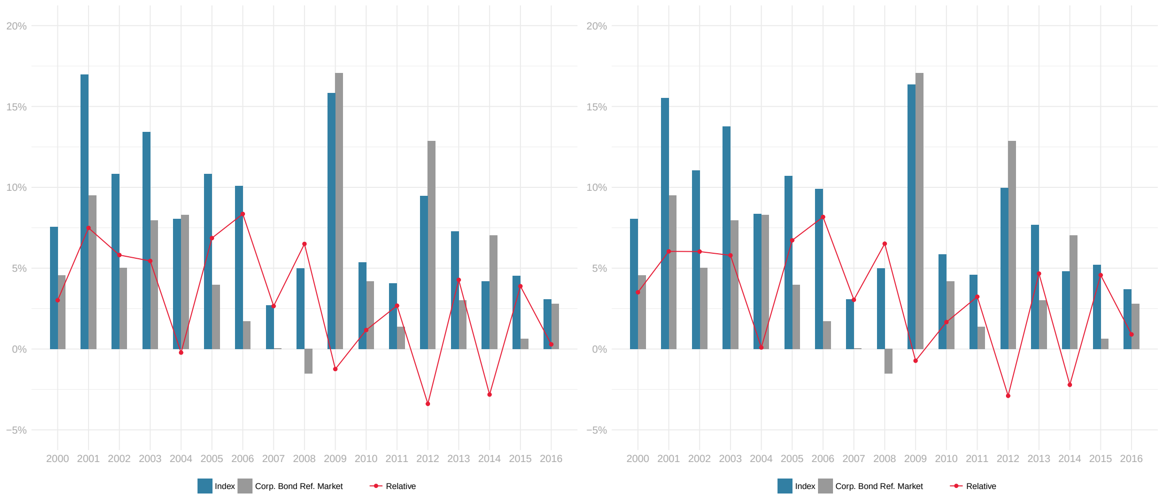

Figure 14: Performance: **Value-weighted** senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016

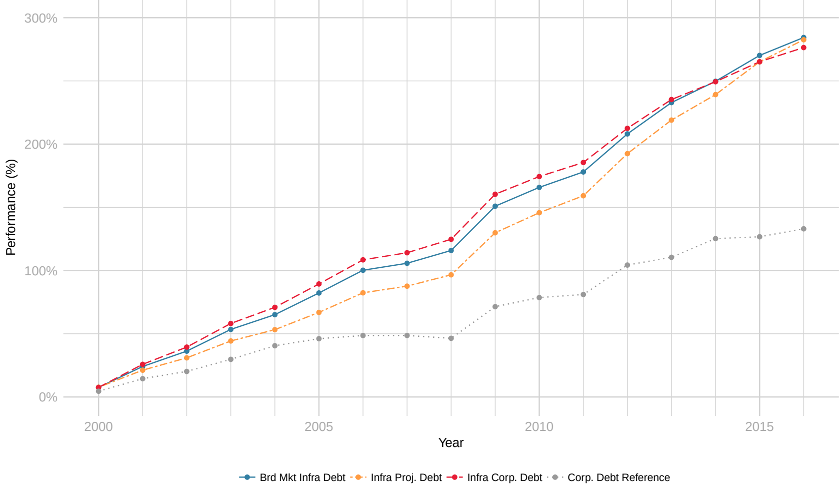

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Figure 15: Performance: **Equally weighted** senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016

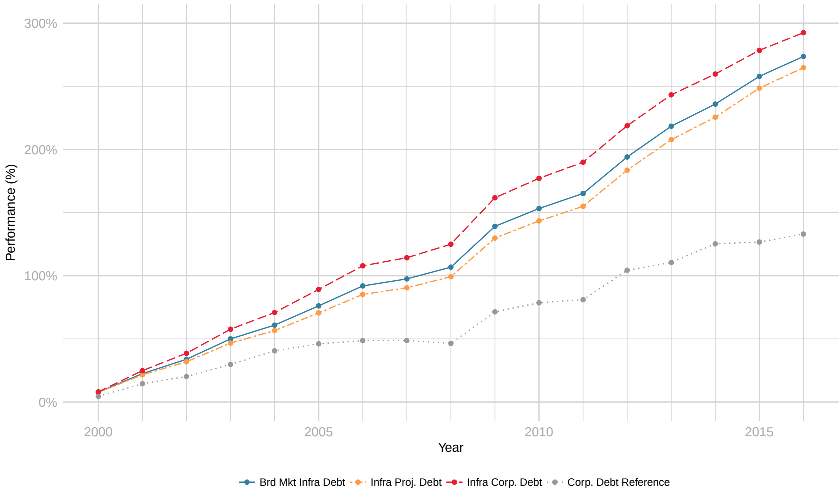

Figure 16: Sharpe ratio: **Value-weighted** senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016

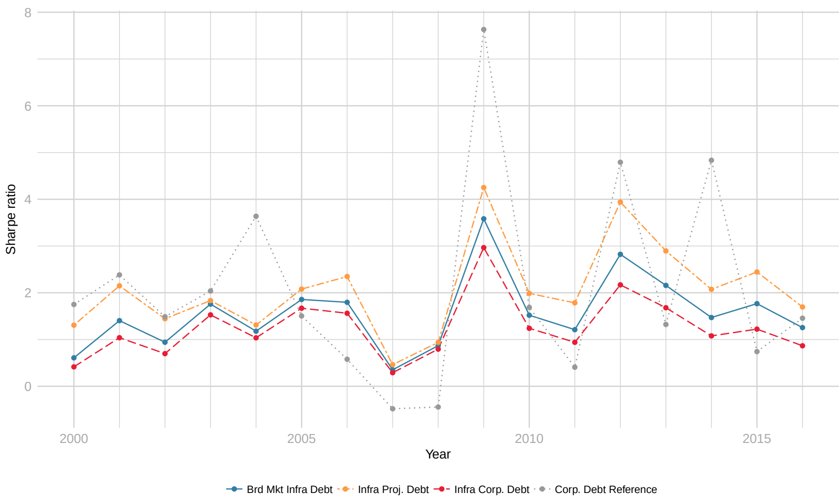

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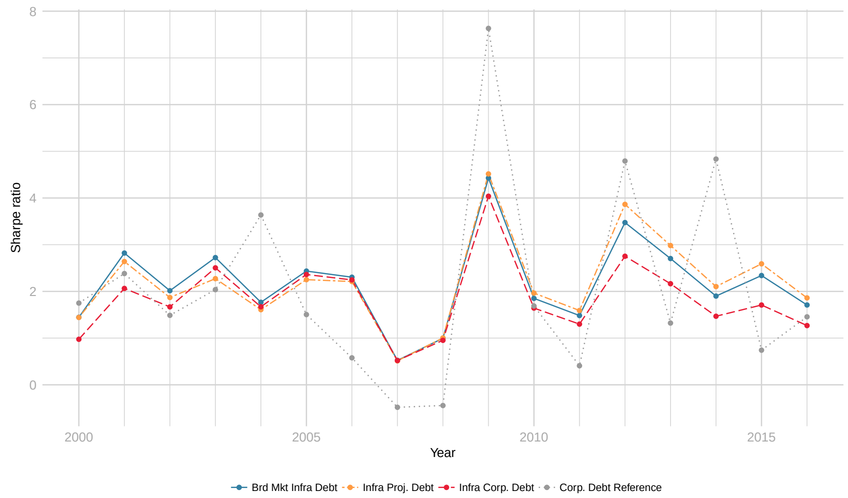
Figure 17: Sharpe ratio: **Equally weighted** senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016



differentiates these two families of debt instruments.

Independently of the weighting scheme, project finance debt tends to outperform both infrastructure corporate debt and the public corporate debt index at all but one[20] reported horizons.

20 - Full history, equally weighted, infrastructure corporate debt outperforms project debt by 50 bps.

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

At the 10-year investment horizon, on an equally weighted basis, infrastructure project debt (panel B2) exhibits annualised returns of 7.07%, followed by infrastructure corporate debt (panel C2) at 6.62%, and senior corporate debt 4.75% (panel D).

This ranking remains true at shorter horizons, with an increasing gap between infrastructure projects and infrastructure corporates. Infrastructure corporates only outperforms project debt over the full sample period, taking into account some larger returns at the beginning of the period.

The return volatility of project debt (panel B2) is also 70-100 bps lower than that of infrastructure corporate debt (panel C2).

As a result, the Sharpe ratios of the project debt index are significantly higher (60-80 bps) than those of the infrastructure corporate debt index.

The Sharpe ratios of infrastructure corporate debt indices also tend to be lower than that of the Corporate Debt Reference index.

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Looking at the annual performance of the equally weighted project and corporate infrastructure debt subindices (figures 12b, 12b), the infrastructure corporate debt index exhibits higher returns until 2009 and the reverse is true for project debt, which only becomes the main driving force behind the performance of the broad market index after 2009.

Performance on a cumulative basis is illustrated by figures 14 and 15. For the reasons highlighted above (large early returns), infrastructure corporate debt achieves a higher cumulative total return, especially on an equally weighted basis, because it recorded relatively higher returns at the beginning of the period before experiencing a faster decrease in annual returns than the infrastructure project debt index.

The Sharpe ratios of project and infrastructure corporate debt also reflect the relative concentration of each index: infrastructure project debt always has a higher Sharpe ratio on a value-weighted basis, whereas on an equally weighted basis its Sharpe ratio is on par with infrastructure corporate debt until 2009, after which it achieves much higher levels of returns per unit of risk.

4.2.3 Yield-to-Maturity

Another measure of performance is available through the yield-to-maturity (YTM or internal rate of return (IRR)) of the three indices, as shown in figure 18, which confirms the results discussed above.

IRR computations are "money-weighted" so they tend to echo the value-weighted index results. There is long-run decreasing tendency in returns, nevertheless infrastructure debt benefits from a significant yield spread compared to the listed corporate debt reference index.

Until 2006, project debt does not offer better YTM than infrastructure corporates but significantly increased the yield spread during the 2007-2014 period.

Since 2014-15, there is an uptick in the YTM trend of infrastructure debt, contradicting the continued decline of yields in the corporate debt universe.

4.3 Risk Metrics

4.3.1 Value-at-Risk

Turning to risk metrics, the value-at-risk (99.5%, Gaussian) and effective duration of the three indices is shown on figures 19 and 20 for value- and equally weighted portfolios, respectively.

Comparing the broad market infrastructure debt index with the Corporate Debt Reference Index, infrastructure debt exhibits higher value-at-risk (VaR), but not the 2008 crisis drop in VaR which is found in the reference index.

The impact of concentration is again obvious, especially in earlier years when infrastructure corporate debt is riskier in the index sample, at a time when it was also yielding historically higher returns.

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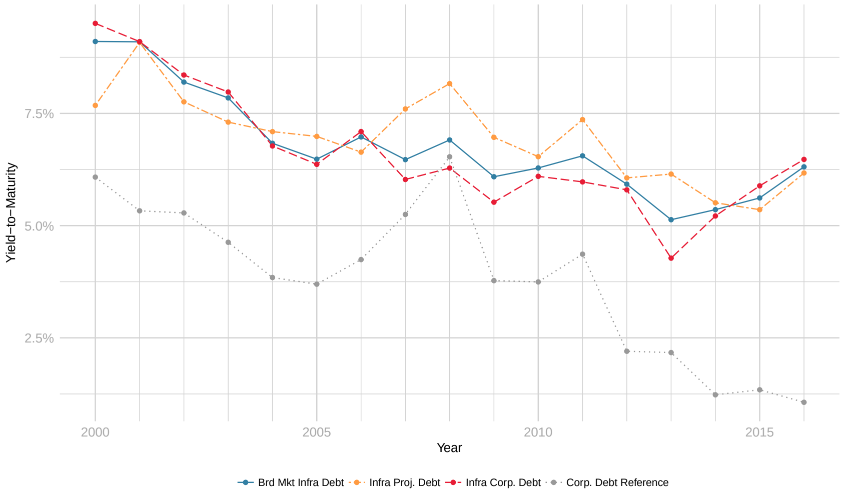
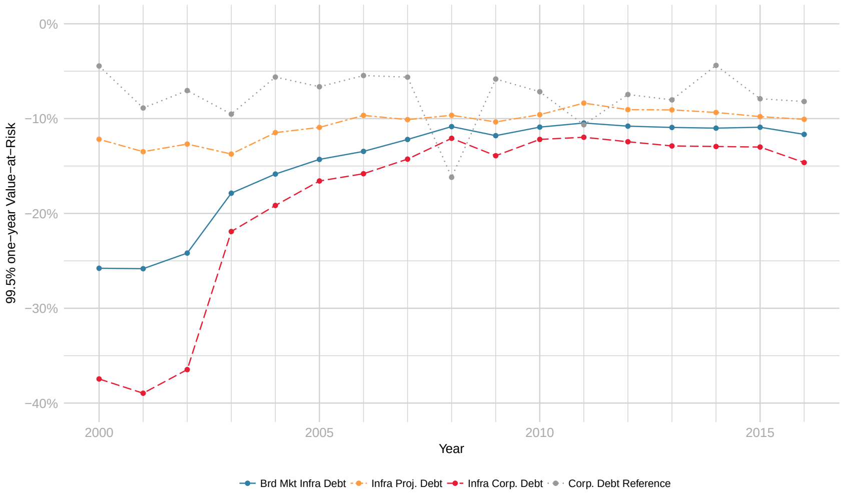
Figure 18: Yield-to-Maturity: senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016



The IRR of the iBoxx Euro Senior Corporate Debt is obtained from Datastream. The IRR of the 3 infrastructure debt indices are computed by the authors.

Figure 19: Value-at-Risk*: **Value-weighted** senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016



*99.5% one-year Gaussian value-at-risk, computed by the authors using the volatility measure of both infrastructure and corporate debt reference indices.

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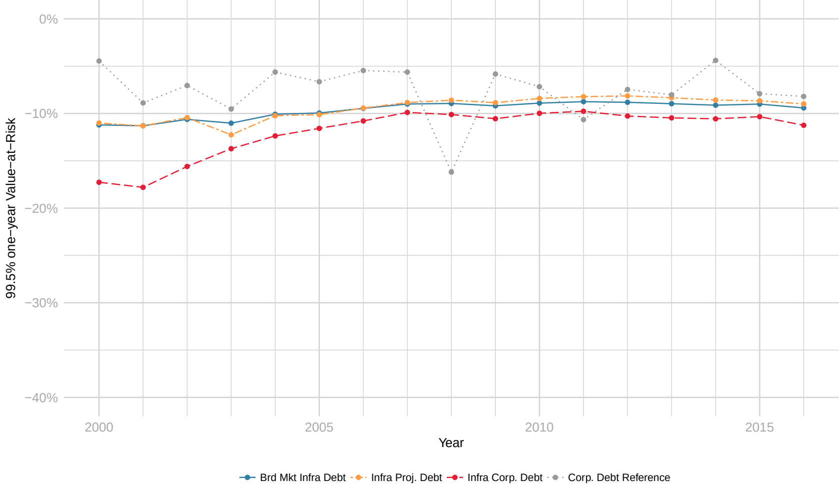
Figure 20: Value-at-Risk*: **Equally weighted** senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016



*99.5% One-year Gaussian value-at-risk, computed by the authors using the volatility measure of both infrastructure and corporate debt reference indices.

On an equally weighted basis the VaR of infrastructure debt is much closer to the market reference. Project debt in particular converges with the VaR of senior corporate debt in Europe toward the end of the period, while infrastructure corporate debt remains higher and below the -10% threshold.

4.3.2 Credit Risk

Portfolio credit risk was measured by computing a default covariance matrix and individual expected-loss estimates for each constituent. Expected loss of the proportion of the face value of each instrument which creditors expect to have to forgo (so-called haircuts) aggregated according to portfolio weights.

Figure 21a shows the probability that *at least* one borrower defaults in the index at each point in time (*PD*1). It can be relatively high as the size of the portfolio increases, even for very low individual default frequencies. This probability of observing at least one default in the broad market index exhibits a clear cyclical pattern.

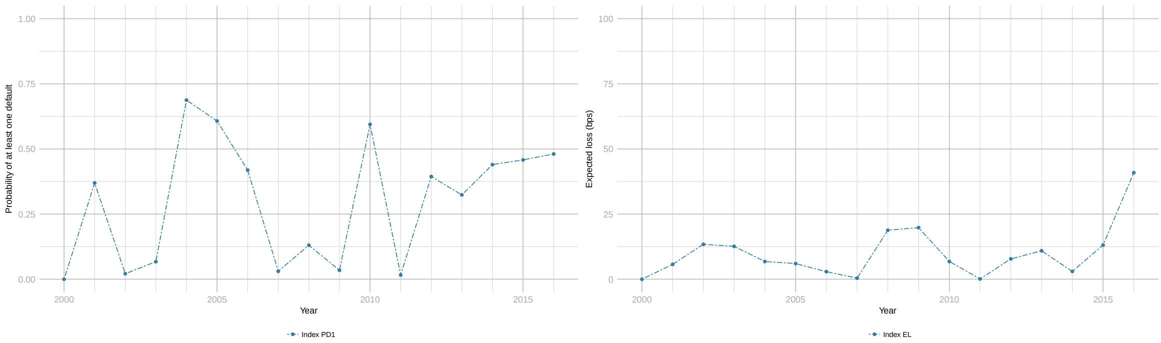
Figure 21b shows the expected loss for the equally weighted broad market infrastructure debt index. This metric is a combination of the likelihood of experiencing defaults in the portfolio in each year (driven by individual borrowers' DSCR levels and volatility), the type of borrowers in the portfolio, and the possibility to restructure their debt at that time in the life of the investment. The broad market index expected loss also follows a cyclical pattern. We note that default risk and expected losses have both increases in the most recent period.

Figure 22a and figure 23a show the equivalent probability of observing a least one default in the two subindices, project and

4. Results

Figure 21: Credit risk: EDHEC*infra* **broad market** private infrastructure debt index, Europe(14), 2000-2016

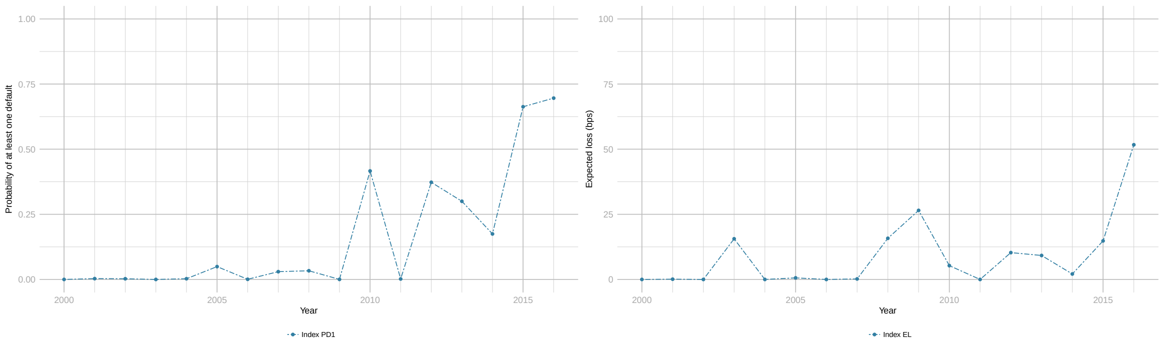
(a) probability of at least one default in the portfolio (b) portfolio Expected Loss



Computed by the authors using a covariance matrix of conditional default frequencies.

Figure 22: Credit risk: EDHEC*infra* private infrastructure **project debt** index, Europe(14), 2000-2016

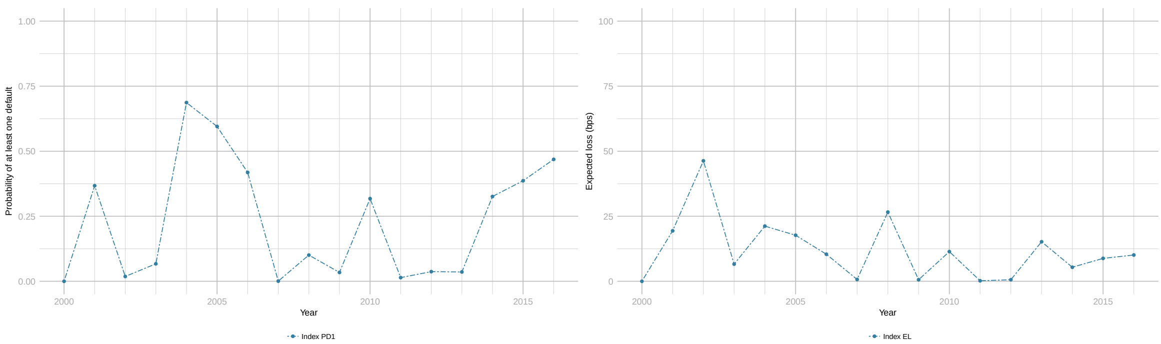
(a) probability of at least one default in the portfolio (b) portfolio expected loss



Computed by the authors using a covariance matrix of conditional default frequencies.

Figure 23: Credit risk: EDHEC*infra* infrastructure **corporate debt** index, Europe(14), 2000-2016

(a) probability of at least one default in the portfolio (b) portfolio expected loss



Computed by the authors using a covariance matrix of conditional default frequencies.

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infrastructure corporate debt. This confirms that cash flow dynamics and credit risk profiles of project and corporate debt are rather different and impacted by different aspects of the investment/business cycle.

As a result of their different default risk and constituents' financial structures, the project and infrastructure corporates indices also have differing expected-loss profiles, as shown in figure 22b and figure 22b. We note that the recent spike in credit risk is really driven by the project subindex.

4.3.3 Duration

Figures 24 and 25 show the effective duration of the broad market infrastructure debt index on a value- and equally weighted basis, respectively. The more concentrated index exhibits greater interest-rate risk, especially in earlier years, consistent with previous measures of risk and return.

While the corporate debt reference index is relatively stable with a duration of 4-5 years, we note a long-term decreasing trend in the infrastructure debt index, albeit less so on an equally weighted basis. Hence, while infrastructure debt had a higher duration than senior corporate debt for most of the period, by 2015, they were effectively on par with each other.

The duration of the project and infrastructure corporate debt subindices sheds some light on the broad market trend. Project-debt duration is on a slight downtrend since 2009, reflecting the gradual inclusion in the index of new, shorter loans, as commercial lenders in particular restricted their long-term lending after the 2008 banking crisis.

Still, the most significant contribution to the observed decrease in duration of the broad market index is the much sharper decrease of infrastructure corporate debt duration, also reflecting a growing tendency to use shorter term finance among such firms.

4.4 Performance Attribution

Finally, figures 26a and 26b describe a "5-factor" decomposition of the return of each infrastructure debt index, which can be estimated from 2000 to 2014.

Here, annual index returns are decomposed into their sensitivity to change in the three standard term-structure factors used in fixed-income models: a) duration or the level of interest rates, b) the slope of the risk-free term structure, and c) its convexity.

Additionally, we consider the impact of changes in the cash flow volatility of index constituents on index returns (i.e. a cash flow beta).

Finally, the unexplained remainder is labeled "market conditions" and is understood to include a bundle of other factors such as country-specific changes, the evolution of investor preferences, etc.

A more complete factor decomposition of the returns of infrastructure debt indices is

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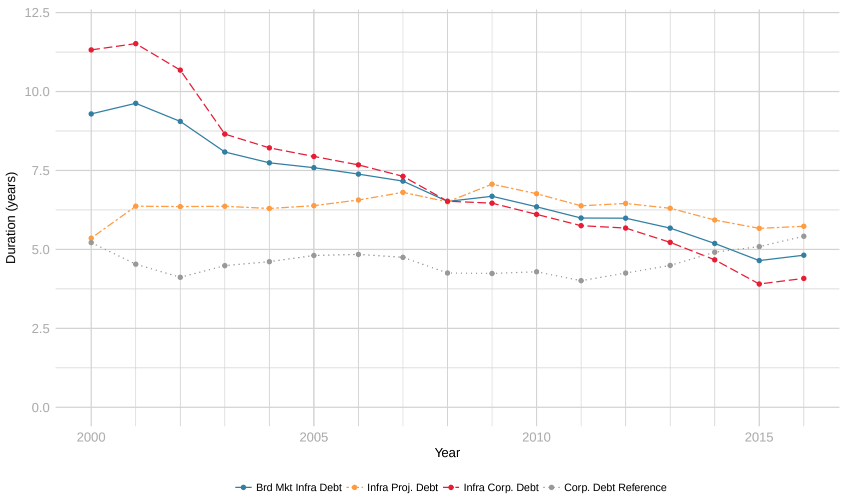
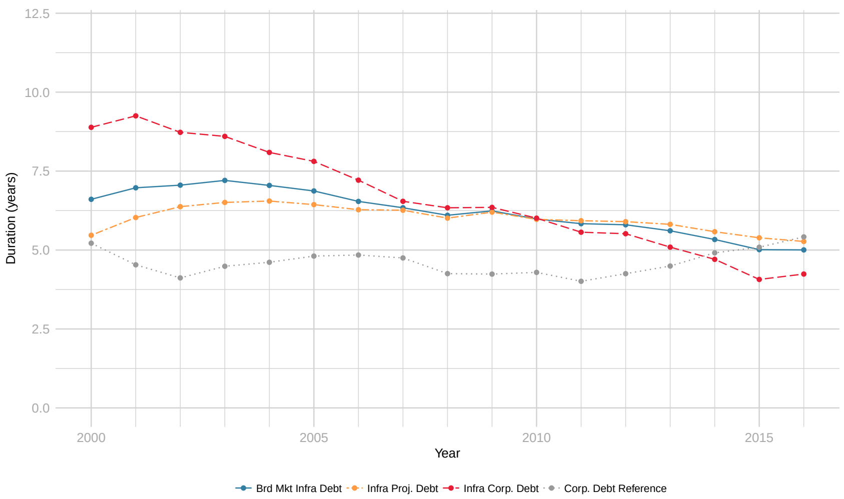
Figure 24: Duration*: **Value-weighted** senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016



*Option adjusted. The duration of the iBoxx Euro Senior Corporate Debt is obtained from Datastream, while that of the 3 infrastructure debt indices are computed by the authors.

Figure 25: Duration*: **Equally weighted** senior private infrastructure debt indices, Europe(14), fully hedged, 2000-2016



*Option adjusted. The duration of the iBoxx Euro Senior Corporate Debt is obtained from Datastream, while that of the 3 infrastructure debt indices are computed by the authors.

Figure 26: Fixed-income factor attribution: EDHEC*infra* **broad market** private infrastructure debt index, Europe(14), fully hedged, 2000-2016

(a) value weighted (b) equally weighted

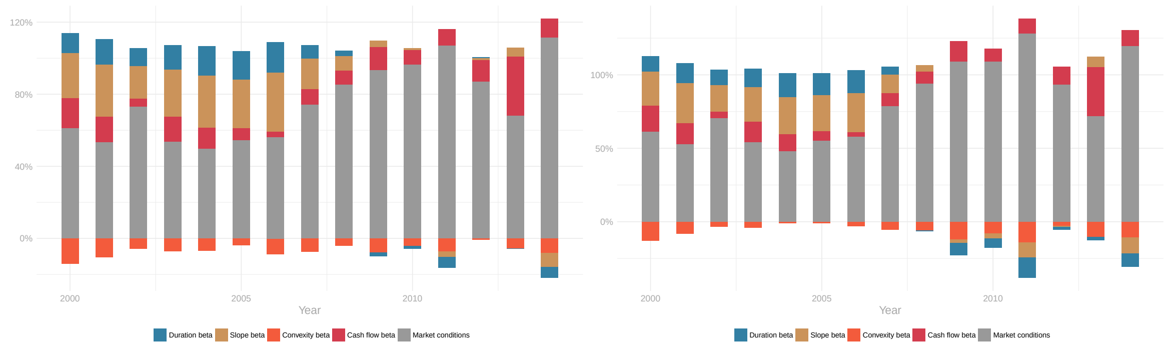


Figure 27: Fixed-income factor attribution: EDHEC*infra* private infrastructure **project debt** index, Europe(14), fully hedged, 2000-2016

(a) value weighted (b) equally weighted

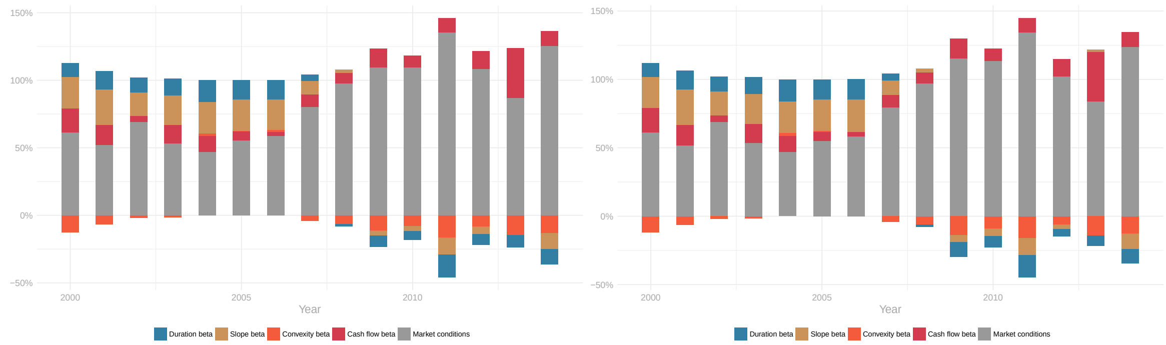
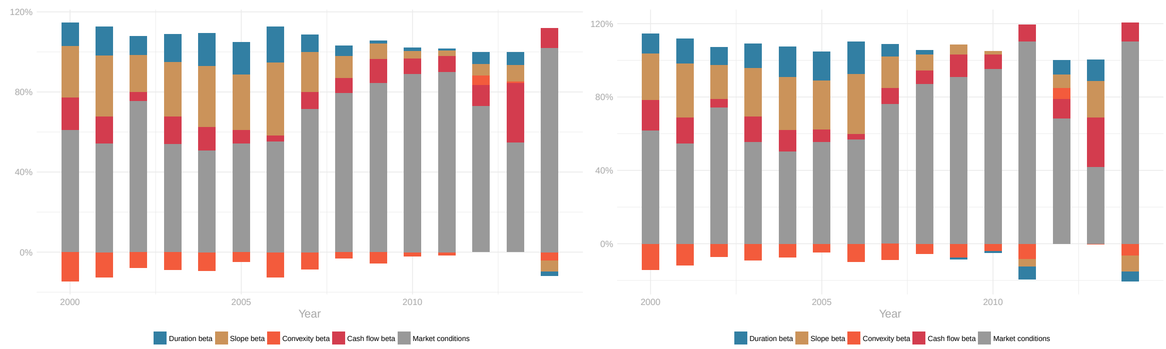


Figure 28: Fixed-income factor attribution: EDHEC*infra* infrastructure **corporate debt** index, Europe(14), fully hedged, 2000-2016

(a) value weighted (b) equally weighted



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beyond the scope of this paper and is a topic of forthcoming research.

We note that the dramatic changes in the term structure of risk-free rates during the period of interest have had a different impact on infrastructure project and infrastructure corporate debt.

In the case of project debt, as shown in figures 27a and 27b, very low base rates after 2008 led to the sign inversion of the duration and slope factor loadings: in other words, decreasing interest rates led, *ceteris paribus*, to an increase in excess returns. This effect is absent from the corporate infrastructure except momentarily in 2011 and 2014.

Higher excess returns for project finance debt since 2008 and the large drop in base rates can be driven by a combination of higher duration than infrastructure corporate debt (hence greater capital appreciation) but also higher creditor pricing power in a highly segmented private debt market during that period.

Likewise, the convexity beta is smaller but also more procyclical for the project debt index than for the infrastructure corporate debt index.

5. Conclusion

5. Conclusion

In conclusion, we can highlight the following stylised facts about the risk-adjusted performance of private infrastructure debt.

The broad European market infrastructure debt index (including project and infrastructure corporate debt)...

1. ...significantly outperforms the European corporate bond debt index over the 2000-2016 period, thanks to a significant yield spread;
2. On a value-weighted basis, the broad market infrastructure debt index exhibits significant concentration and its Sharpe ratio or risk-adjusted performance is not significantly different from that of the corporate bond index;
3. However, it exhibits higher risk-adjusted performance on an equally weighted basis, when its level of concentration is equivalent to that of the corporate bond index;
4. The duration and value-at-risk of our broad market index are higher than the listed senior corporate bond reference index, justifying higher returns, but also exhibiting converging tendencies over the period.

The European broad market senior infrastructure index clearly behaves differently than its senior corporate bond comparator, but the difference on a risk-adjusted basis is not always very "clean." Examining the behaviour of the two subindices which make up this broad market measure allows a more granular understanding.

The infrastructure project finance senior debt index...

1. ...does not deliver a better cumulative outperformance than the Broad Market Infrastructure Debt Index over the entire period;
2. Still, its yield spread is higher than the broad infrastructure debt market's after 2006, and project finance debt has been the best performer at the 10-year horizon or lower, by a substantial margin;
3. On a risk-adjusted basis, for either value- or equally weighted portfolios, project-finance debt improves on the corporate bond index by 30-60 basis points (per unit of risk) at different horizons;
4. Duration and value-at-risk are consistently higher than the corporate debt index by a relatively small and decreasing margin over the period;
5. In terms of return volatility, the project finance debt index has the lowest risk profile.

Finally, the infrastructure corporates senior debt index...

1. ...delivers a better cumulative performance than corporate bonds or project-finance debt over the 16-year period primarily due to higher returns in earlier years;
2. After 2006 its yield spread is much lower than that of project-finance debt, even though it bounces back in 2013;
3. Critically, on a risk-adjusted basis, even looking at the more diversified equally weighted index, infrastructure corpo-

5. Conclusion

rates fails to deliver a Sharpe ratio that improves on that of the public corporate bond reference index (i.e., infrastructure corporate debt may have higher returns but it also is much more volatile both than corporate bonds or project finance debt);
4. European infrastructure corporates have the highest value-at-risk of the different indices considered.

We conclude that while infrastructure project finance debt has a unique risk-reward profile, infrastructure corporates probably cannot qualify as a new asset class. With a Sharpe ratio that cannot be distinguished from that of the listed senior corporate bond market reference, infrastructure corporates are a higher-risk/higher-return subset of the senior corporate bond bucket.

Why is infrastructure project finance debt different? An intuitive explanation is provided by Esty (2003) when he argues that in project finance, high leverage can be interpreted as a sign of low asset risk. Blanc-Brude and Ismail (2013) developed this argument in an agency context: the control rights that limited-recourse project finance creates for creditors allow for a better-informed use of leverage, because the use of funds by the firm's owners is highly restricted.

As a result, whereas corporates (infrastructure or not) present investors with the classic problem that the largest borrowers are also the biggest credit risks, in project finance, this logic is reversed. Project vehicles are allowed to be highly leveraged only because the probability of timely repayment is very high.

Infrastructure corporates exhibit a higher volatility of returns because their leverage (which has been increasing over the period) makes them a greater credit risk.

Conversely, part of the outperformance of project finance debt is not driven by credit risk or return volatility. This is evidenced by the unique relationship between excess returns and the term structure of risk-free rates. In the case of corporate debt, lower base interest rates since 2007 are associated with lower spreads, that his, *ceteris paribus* a lower cost of debt decreases a corporate borrower's credit risk, and the associated returns. With project finance debt, this mechanism is, again, reversed: lower base interest rates have, since 2007, corresponded to an *increase* in spreads.

Part of this increase in debt spreads has been driven by lenders' costs of funds and regulation, since the vast majority of them remain banks. But these changes in commercial banks' funding conditions also apply to lending to infrastructure corporates. Instead, for a given level of credit risk, lower base rates have allowed for an increase in profitability of project finance lending.

In conclusion, looking at 16 years of data for 14 European countries, a private infrastructure senior debt index exhibits

5. Conclusion

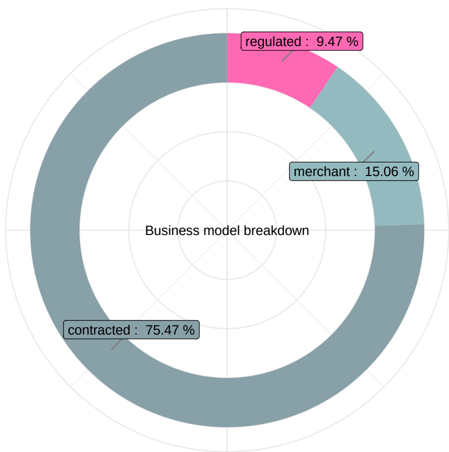
investment characteristics that set it clearly apart from a senior corporate debt index. However, this broad market infrastructure debt index is composed of two subgroups of assets that have different profiles: the first one, infrastructure project finance, has a unique risk/reward profile and offers a relatively high reward per unit of risk, especially since 2007; the second one, infrastructure corporate debt, is a higher-risk/higher-return version of the corporate debt market but does not offer a better level of risk-adjusted performance than corporate debt.

6. Appendix

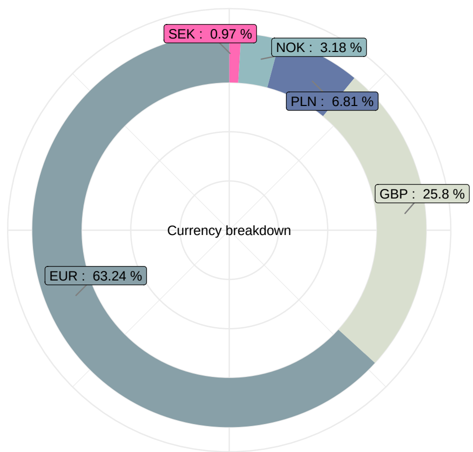
6. Appendix

Figure 29: EDHEC*infra* private **infrastructure project debt** index, fully hedged, 2016 breakdown by market value, **value weighted**

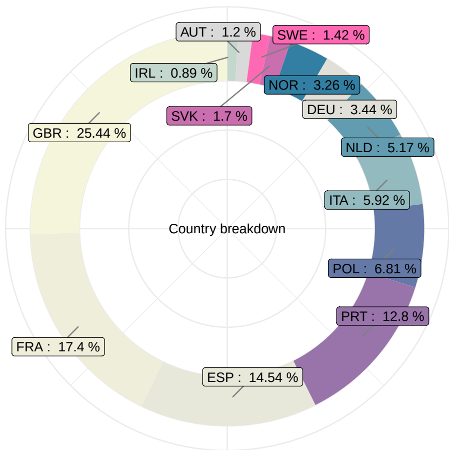
(a) business model breakdown



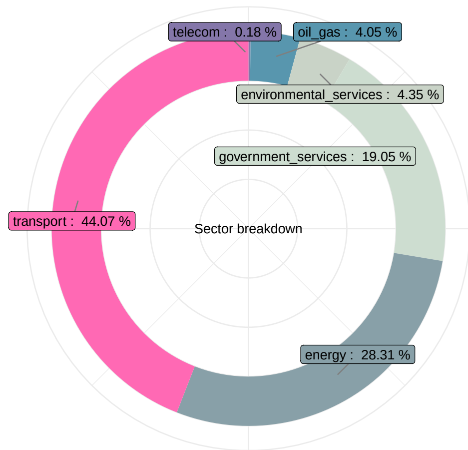
(b) currency breakdown



(c) country breakdown



(d) sector breakdown

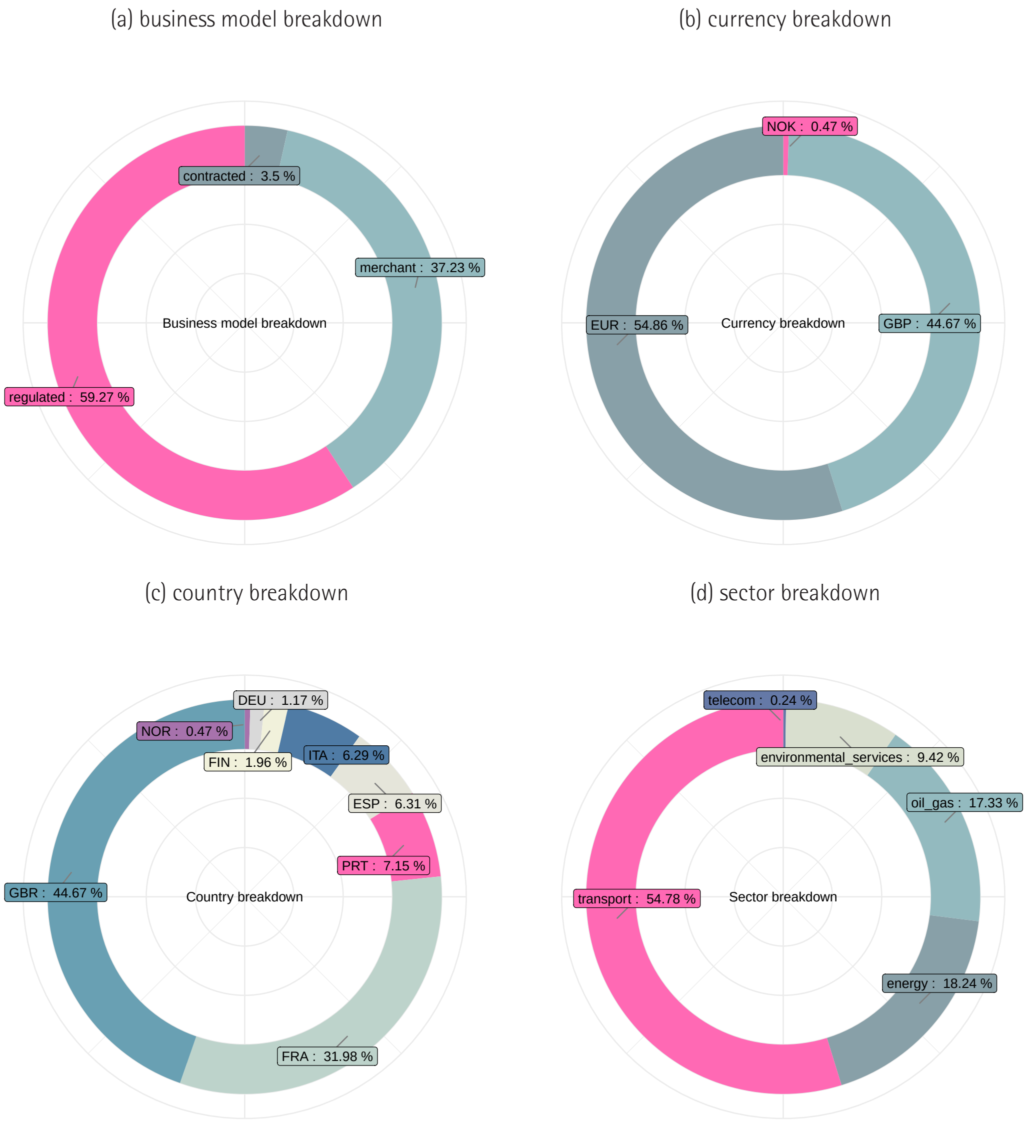


6. Appendix

Figure 30: EDHEC*infra* private **infrastructure project debt** index, fully hedged, 2016 breakdown by market value, **equally weighted**

6. Appendix

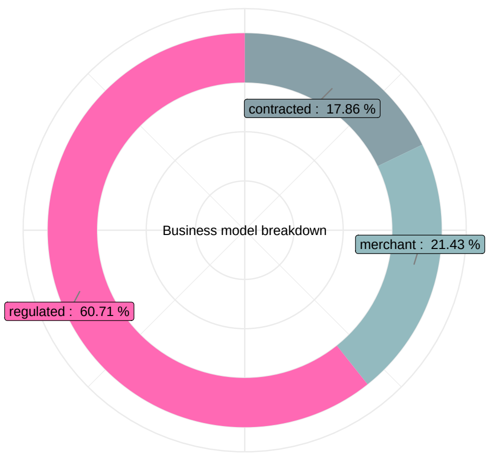
Figure 31: EDHEC*infra* **corporate infrastructure debt** index, fully hedged, 2016 breakdown by market value, **value weighted**



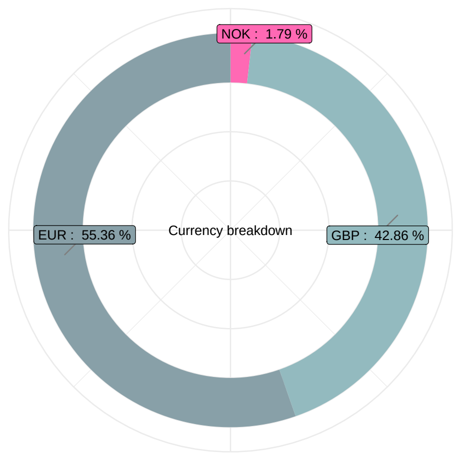
6. Appendix

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

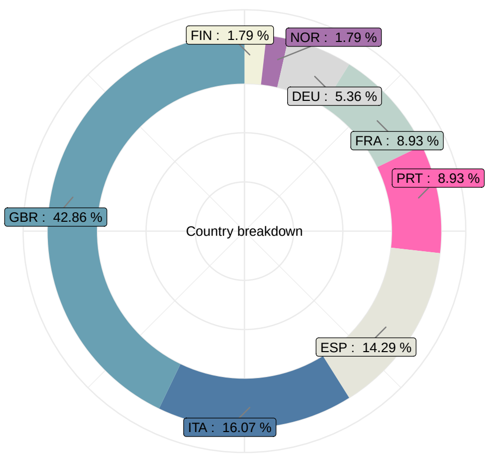
(a) business model breakdown



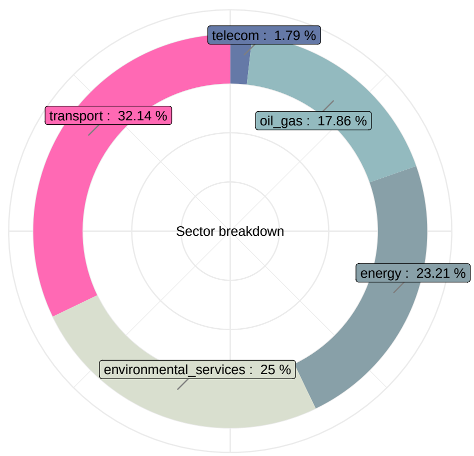
(b) currency breakdown



(c) country breakdown



(d) sector breakdown



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About Natixis

About Natixis

Natixis is the international corporate, asset management, insurance, and financial services arm of Groupe BPCE, the second-largest banking group in France, with 31.2 million clients spread over two retail banking networks, Banque Populaire and Caisse d'Epargne.

With more than 16,000 employees, Natixis has a number of areas of expertise that are organised into three main business lines: Corporate & Investment Banking, Investment Solutions & Insurance, and Specialized Financial Services.

A global player, Natixis has its own client base of companies, financial institutions, and institutional investors as well as the client base of individuals, professionals, and small- and medium-size businesses of Groupe BPCE's banking networks.

Listed on the Paris stock exchange, it has a solid financial base with a CET1 capital under Basel 3(1) of Eur12.6 billion, a Basel 3 CET1 Ratio o [21] of 11.0% and quality long-term ratings (Standard & Poor's: A / Moody's: A2 / Fitch Ratings: A).

21 - Based on CRR-CRD4 rules as reported on June 26, 2013, including the Danish compromise - without phase-in except for DTAs on tax-loss carryforwards following ECB regulation 2016/445. Figures as at March 31, 2017

Natixis is a recognised player in the infrastructure space and has notably obtained the following rankings, in 2016:

- #10 Global MLA - Sources: IJ Global – Full Year 2016 Global Infrastructure Finance League Tables; PFI-Full Year 2016 Project Finance International League Tables; InfraDeals 2016 Project finance and advisory league tables
- #9 Global Bookrunner – Source: Thomson Reuters – Global Project Finance Review Full Year 2016
- #6 Americas Advisory Mandates Won – Source: PFI-Full Year 2016 Project Finance International League Tables
- #7 MLA in Europe – Source: IJ Global – 2016 Full Year League Tables
- #5 Worldwide in Renewables, #1 in Europe – Source: IJ Global – 2016 Full Year League Tables
- #3 Worldwide in Telecoms – Source: IJ Global – 2016 Full Year League Tables

More information on Natixis infrastructure expertise available at: http://cib.natixis.com/infrastructure.

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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EDHEC Infrastructure Institute Publications

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