PUBLISHED BY | AUGUST 2017 • VOLUME 1, NUMBER 15 | A SUPPLEMENT TO PENSIONS & INVESTMENTS

P&I CONTENT SOLUTIONS GROUP

Research for Institutional Money Management

Infrastructure Benchmarking Special Issue

EDHECinfra
Infrastructure Institute - Singapore

INTRODUCTION

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Professor of Finance, Associate Dean for Business Development,
EDHEC Business School, CEO, ERI Scientific Beta

It is my pleasure to introduce the latest issue of the Research for Institutional Money Management supplement to Pensions & Investments, which aims to provide institutional investors with an academic research perspective on the most relevant issues in the industry today.

This issue is an Infrastructure Benchmarking Special. We first address the rise of #fakeInfra and how it has been an obstacle to the development of real infrastructure investment. There is no such thing as a "listed infrastructure asset class." It is presented to investors as an opportunity to gain exposure to something new or rare, but has really always been available — that is, it is already "spanned" by existing capital market and other instruments.

We prove our point with a study of listed infrastructure, showing that any "listed infrastructure" effect was already spanned by a combination of capital market instruments over the past 15 years in Global, U.S. and U.K. markets.

We then present the results of private-equity and private debt indexes. On the private-equity side, we created the ability to measure the risk-adjusted performance of private infrastructure equity investments on a comparable basis with other asset classes. These results allow asset owners and managers to begin to evaluate how they might better access infrastructure investments, so that infrastructure investing can become a means to an end and help them meet their investment goals in a more meaningful manner.

On the debt side, we conclude that 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.

We describe how investors need their private asset managers to adopt better valuation methods. Asset owners are winning the argument to lower private-equity manager fees; their next battle will be about the valuation of private assets.

Finally, we detail our approach to private equity and debt valuation used to build the infrastructure investment benchmarks created by EDHECinfra.

We hope that the articles in the supplement will prove useful, informative and insightful. We wish you an enjoyable read and extend our warmest thanks to Pensions & Investments for their partnership on the supplement.

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Access to Infrastructure Investment and #fakeInfra

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As EDHECinfra releases 384 indexes of private infrastructure equity and debt investments, we hope that these results will help dissipate the confusion created by #fakeInfra.

Almost every day, asset owners are presented with new opportunities to invest in "infrastructure." The appeal is always the same: yield, stability, a degree of portfolio diversification, and perhaps even inflation hedging.

But this label has been stuck on more than one tin. And a serving of infrastructure can now come in many forms: from private-equity funds with various horizons and mandates, to ETFs and other funds of publicly traded equities, to green bonds or infrastructure REITS.

Many investment products may have a new "infrastructure" look but it is possible that they have nothing new or special to offer — it is just repackaging or confusing packaging.

"Listed infrastructure" is a case in point. As our recent study of the (absence of) unique characteristics of 22 listed infrastructure proxies meets its destiny in a peer-reviewed journal, a key finding stands out: there is no such thing as a "listed infrastructure asset class."

This study, which is summarized in this supplement, highlights the importance of discussing the existence of new "asset classes" in a total portfolio context whether they are built by broad asset classes of assets or by risk factors. Using mechanical stock filters or industry-provided thematic indexes, we conduct 176 mean-variance spanning tests both pre- and post-GFC in Global, U.S. and U.K. markets, and find zero evidence that focusing on "listed infrastructure" creates any new and persistent diversification benefits for already well-diversified investors.

"Listed infrastructure" is #fakeInfra

It is presented to investors as an opportunity to gain exposure to something new or rare, but has really always been available — that is, it is already "spanned" by existing capital market and other instruments.

#fakeInfra relies on the flexible definition of real world "infrastructure" to invest in businesses which may be related to the "monopoly provision of essential services" but do not necessarily need a new label for investors — what matters to investors is to achieve their objectives at the relevant horizon, not to own companies from a particular sector of the economy.

Today, a listed infrastructure fund is just an active equity fund with a narrow industrial focus. It is an alpha-driven product, often mislabeled as a new form of beta. It is not what investors need to better understand the potential role of infrastructure and real asset investing in their portfolio.

There are also plenty of examples of #fakeInfra beyond the listed equity space. What is a "core" or "core+" infrastructure asset? Is this kind of classification helpful to address asset allocation questions or the prudential treatment of infrastructure investment?

The future of real asset investing

Now, thanks to an EDHEC initiative supported by the industry, as well as the Singapore government, the growth of #fakeInfra, listed or not, may begin to abate.

In June we are releasing two series of 192 indexes of the risk-adjusted performance of hundreds of private European infrastructure equity and debt investments, going back to 2000.

Thanks to the largest database of infrastructure investment data in the world (with close to three million cash flow and balance sheet data points) and a unique asset pricing technology designed to estimate the performance of private, highly illiquid assets like infrastructure debt and equity, EDHECinfra can produce the risk-adjusted performance metrics that investors and regulators need to understand private infrastructure debt and equity as asset classes.

The news is good: we find that investing in private infrastructure assets can indeed generate out-performance, diversification or better duration hedging. It can have lower value-at-risk than major market benchmarks (suggesting a better prudential treatment under Solvency-II, for example) and its Sharpe ratio can be significantly higher than that of indexes typically used as market references.

But not always

There are two major catches: corporate structure (or asset selection) and portfolio diversification.

Firstly, not all infrastructure firms are created equal — some may have a natural monopoly (and a regulator to boot) and provide essential services, but they are also "just firms." Their board of directors can take them in a number of directions, including leveraging the balance sheet (or more rarely, the opposite), reinvesting earnings and not paying dividends, or pursuing an acquisition strategy, including internationally. All of these are perfectly legitimate decisions that also tend to make this firm less special or less unique when compared with other corporate investment opportunities.

Conversely, project-specific firms are created for one purpose only: delivering infrastructure and operating it while repaying its creditors and owners over a finite period of time. Its board cannot decide to do much else that would change the nature of the business, except refinancing or restructuring its senior debt. In fact, if it was not for the careful crafting of long-term, limited recourse finance, these firms would not even exist.

Real results

The EDHECinfra indexes described in the rest of this supplement reveal that while infrastructure as a "broad market" (i.e., including both types of corporate structures) outperforms the equity reference indexes, on a risk-adjusted basis, infrastructure projects have been doing the majority of the heavy lifting. In comparison, the so-called "infrastructure corporates" are often as volatile as the market reference.

These results are even stronger on the debt side.

The second key element revolves around the ability of investors to diversify their infrastructure investments. Individually, they are often sizeable and as a result many investors find themselves exposed to only a handful of assets, either directly or through a manager.

Our indexes show that while individual investments can be quite volatile, most of this volatility is project-specific — that is, in a large portfolio it is diversified away. Hence, the Sharpe ratio of our broad market infrastructure index, especially on an equally weighted basis, is very attractive.

But this index is also not directly investable.

Tomorrow: real access

Tomorrow, the ability of investors and managers to gain access to infrastructure investment on a well-diversified basis will make all the difference between an attractive investment opportunity and a few highly concentrated bets, which may or may not turn out well.

In a world where measuring such metrics has become possible and better infrastructure investment products can be imagined, #fakeInfra can become a thing of the past, and real asset investing can begin to enter adult life. •

There are also plenty of examples of #fakeInfra beyond the listed equity space.

EDHECinfra private debt and equity benchmarks are drawn from the two research chairs at EDHEC sponsored by Natixis, the Long-Term Infrastructure Investors Association and the Monetary Authority of Singapore.

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Is Listed Infrastructure an Asset Class?

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In a paper recently published in the Financial Market and Portfolio Management Journal (Blanc-Brude et al. 2017), we ask the question, does focusing on listed infrastructure stocks create diversification benefits previously unavailable to large investors already active in public markets?

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

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

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

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

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

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

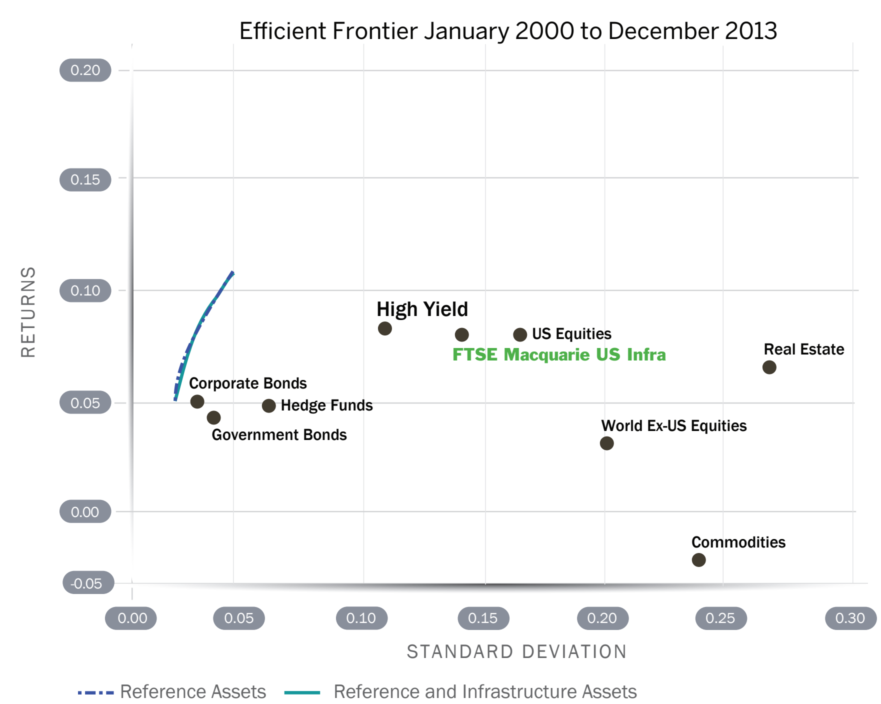
Testing 22 proxies of listed infrastructure

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

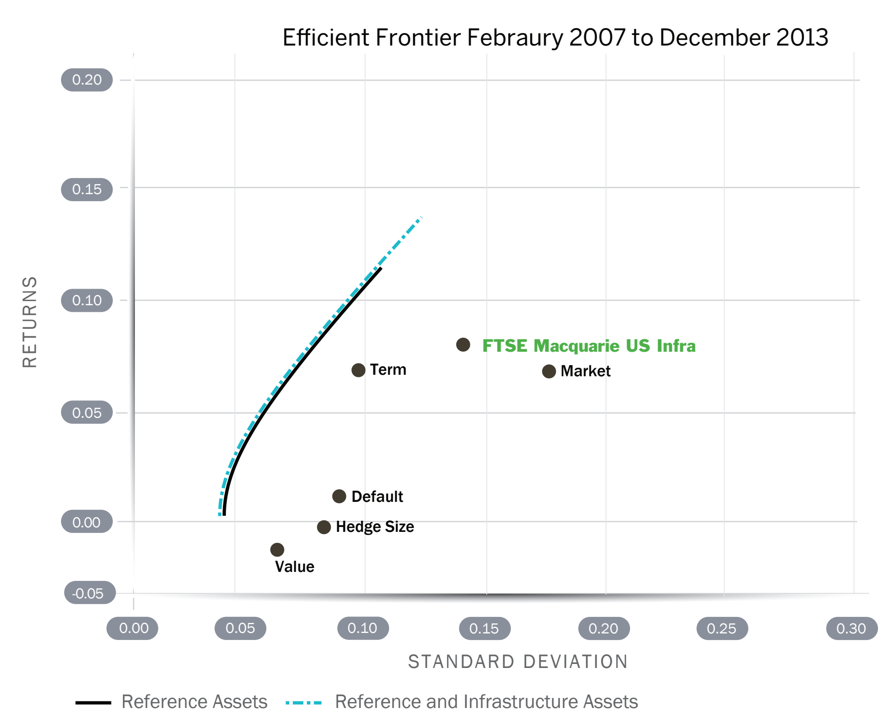
1. A "naïve", rule-based filtering of stocks based on industrial sector classifications and percentage income generated from pre-defined infrastructure sectors (nine proxies);
2. Existing listed infrastructure indexes designed and maintained by index providers (twelve proxies);
3. A basket of stocks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

EXHIBIT 1

1A. Mean-variance spanning test of the FTSE Macquarie USA against asset classes and factor reference portfolios, 2000-2015



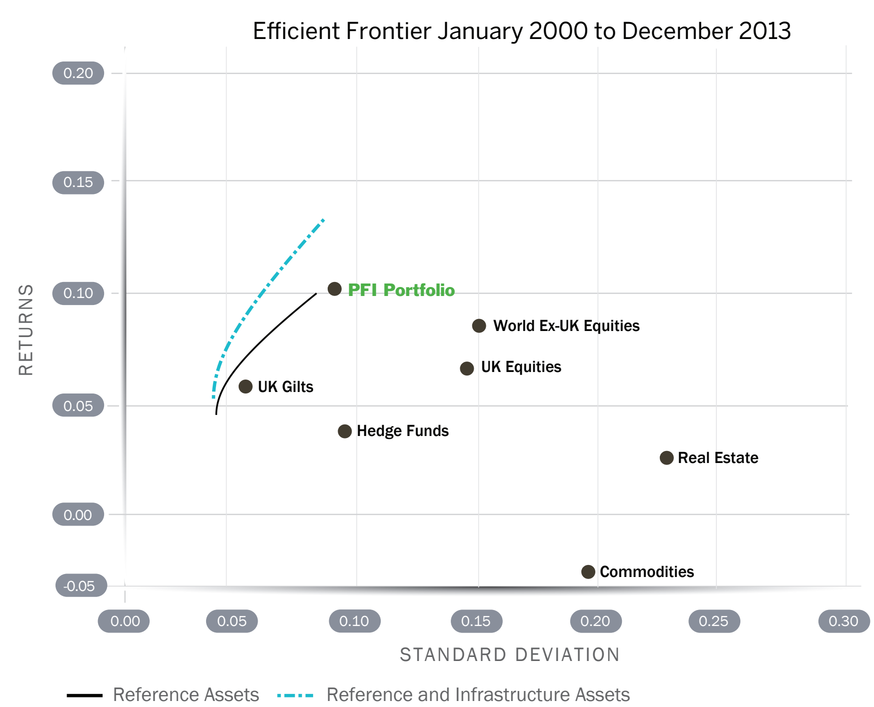
1B. Risk factor reference portfolio



we ask the question, does focusing on listed infrastructure stocks create diversification benefits...

EXHIBIT 2

Mean variance spanning test of the 'PFI' portfolio



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

There is no listed infrastructure asset class

Stylized findings include:

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

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

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

We conclude that what is typically referred to as listed infrastructure, defined by SIC code and industrial sector, is not an asset class or a unique combination of market factors, but instead cannot be persistently distinguished from existing exposures in investors' portfolios, and that expecting the emergence of a new or unique "infrastructure asset class" by focusing on public equities selected on the basis of industrial sectors is unlikely to be very useful for investors.

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

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

Defining infrastructure differently

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

The answer to our initial question partly depends on how "infrastructure" is defined and understood as an asset selection scheme.

Under our third definition of infrastructure, which focuses on the relationship-specific and contractual nature of the infrastructure business, we find that listed infrastructure may help identify exposures that have at least the potential to persistently improve portfolio diversification on a total return basis, as figure 2 illustrates. This effect is driven by the regularity and the size of dividend payouts compared to other corporations, infrastructure or not.

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

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

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

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Private Infrastructure Equity Investment Benchmarks

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A new paper drawn from the work of the EDHEC/LTIIA[1] research chair presents the first results of an ambitious applied research project to create and compute fully fledged private infrastructure equity investment benchmarks.

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

In this first paper using the EDHECinfra database and private asset pricing technology, we focus on three questions:

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

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

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

Building a representative sample of the private infrastructure market

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

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

- Given a region and its core countries, we first document the structure of the investible infrastructure sector in each national market. This includes documenting how investors might become the owner of either individual project companies or special purpose vehicles (SPVs), or of firms that operate in a limited group of industrial sectors and focus narrowly on the provision of infrastructure-like services. These include ports, airports, firms engaged solely in energy distribution, water treatment and distribution or other activities typically understood to correspond to infrastructure.
- We identify which broad categories each identified firm belongs to, such as sector, type of corporate structure and business model.
- We then build a representative sample for the whole region in line with country, sector, corporate structure and business model distribution of all investible infrastructure firms (an approach known as stratified sampling).

Thus, we avoided creating biases in the data collection by overweighting data made available by any one contributor. Over the 15-year period of this study, our market sample consistently represents at least 50% of the total asset value of investible infrastructure firms in Europe, ensuring a significant degree of market coverage of the broad market index.

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

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

Following the EDHECinfra 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, analyzed and validated by a series of algorithms and a team of human analysts. Each firm's data is reviewed iteratively at five different levels of validation including computer-generated and human checks.

Here, we study a sample of 400 firms that are representative by sector and business model of 14 European markets including the U.K., and covers both infrastructure projects and so-called infrastructure corporates.

A fully fledged performance measurement technology

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

Hence, the risk-adjusted performance of the equity invested in each firm in the index sample is derived by forecasting cash flows or payouts to the owners, including any shareholder loans, fees, etc., and discounting them on the basis of the volatility of future payouts forecast at time t, duration, i.e., the remaining life of the investment, and available price information in each period (including the initial value of the investment and comparable transactions taking place each year).

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

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

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

- A model of the "free cash flow to equity" (FCFE) until the end of the investment life is implemented using information about the firm's revenues, capital and operating costs, as well as its capital structure, debt service cover ratio and forecast debt service.
- The mean and variance of each firm's FCFE "retention rate" (RR, i.e., Cash at Bank end of period/FCFE) is estimated in all realized periods and a forecast is made for the remainder of the firm's life.
- The combination of the forecast of the mean and variance of FCFE and RR allows a stream of expected equity payouts to be computed as well as their conditional volatility.
- Firms are grouped by risk "clusters" or buckets, as a function of their payout volatility and time to investment end (duration).
- Within each risk bucket, a term structure of discount factors (and its range) is derived, reflecting the value of the investment relative to expected payouts and conditional (future) payout volatility, as well as any relevant and observable market prices (primary and secondary transactions) in each year.
- Finally, after individual performance metrics have been obtained for each firm's senior debt, a return co-variance matrix is estimated for each reference index (and sub-index) and individual assets are aggregated following preset inclusion and re-balancing rules.

Six key indexes

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

- A **Broad Market Infrastructure Index**, covering 14 European countries and six industrial sector groups, includes 330 "live" firms in 2016, with a capitalization of EUR 293.5 billion. Over the period, 398 firms have been included in the index at one point;
- A **Private Infrastructure Project Equity Index** for the same geography, including 235 live firms in 2016 for a capitalization of EUR 68 billion;
- An Infrastructure Corporate Equity Index also covering Europe, with a EUR 225.5 billion capitalization in 2016 for 95 live firms;
- A Contracted Infrastructure Equity Index with 195 live constituents in 2016 or EUR 47.2 billion of capitalization;
- A Merchant Infrastructure Equity Index including 70 live firms and a total capitalization of EUR 75.2 billion;
- A Regulated Infrastructure Equity Index with 65 live 2016 constituents and representing EUR 171 billion in capitalization.

Index constituents may have been removed from the "live" index because they have reached minimum size threshold, because the firm went bankrupt and was liquidated, or it was sold following a restructuring event.

In order to best capture any infrastructure-specific effect, we focus on the so-called fully-hedged version of each index, which ignores the impact of foreign exchange movements on returns. Each set of index constituents can be broken down by infrastructure "business model," instrument currency, country of origin, industrial sector or corporate structure.

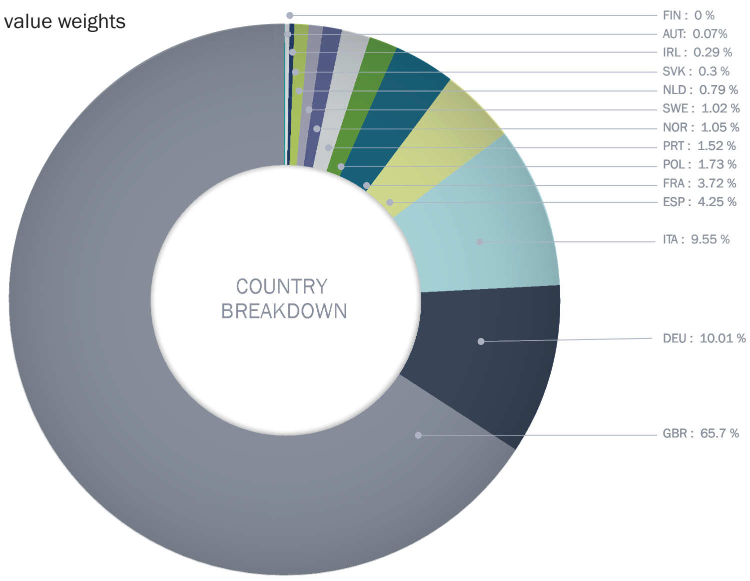
Exhibits 1-3 show the composition of the Broad Market Infrastructure Equity Index by country, sector and business model, on a value-weighted and equally weighted basis.

[1] *The Long-Term Infrastructure Investor Association, with additional support from the Long-Term Investor Club and Campbell-Lutyens*
[2] *E.g. incorporation, construction start and completion, operational phases start, defaults, refinancing and restructuring, pre-payments, 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.*

EXHIBIT 1

1A & 1B: EDHECinfra Broad Market Infrastructure Equity Index, 2016 Country Breakdown by Market Value

value weights



equal weights

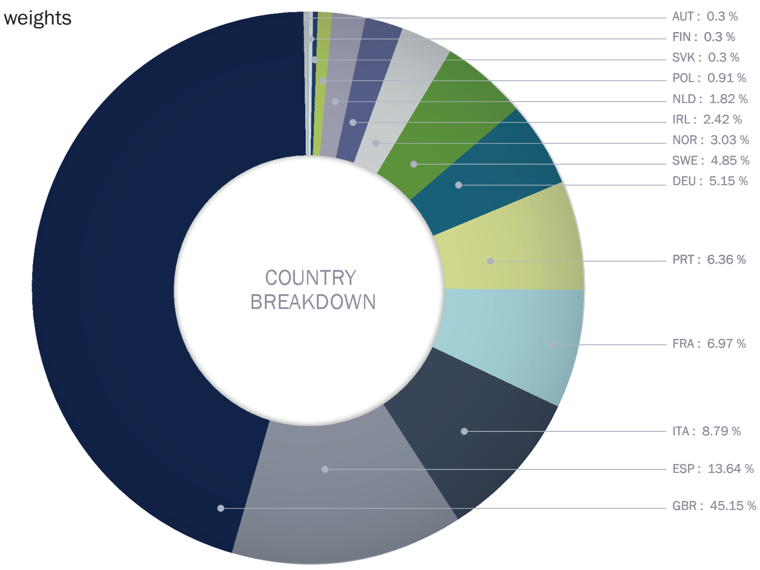
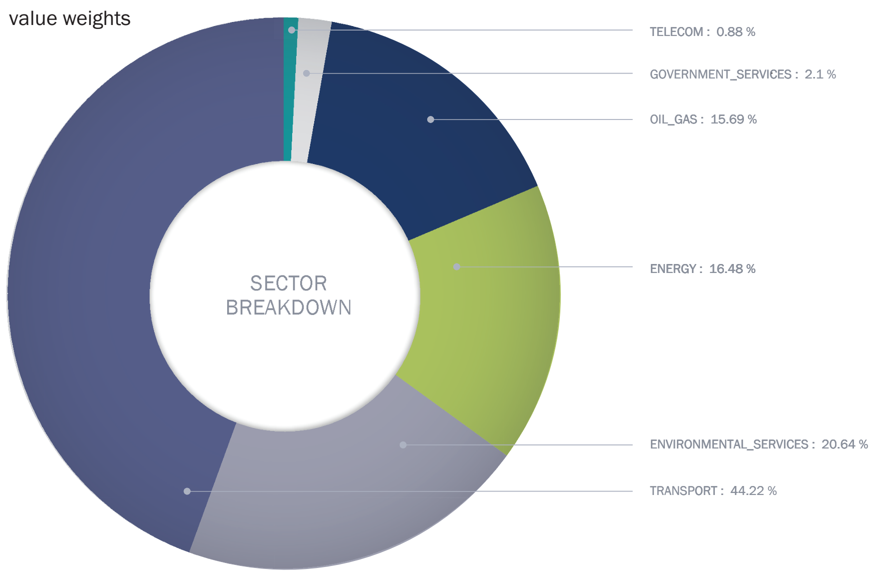


EXHIBIT 2

2A & 2B: EDHECinfra Broad Market Infrastructure Equity Index, 2016 Sector Breakdown by Market Value

value weights



equal weights

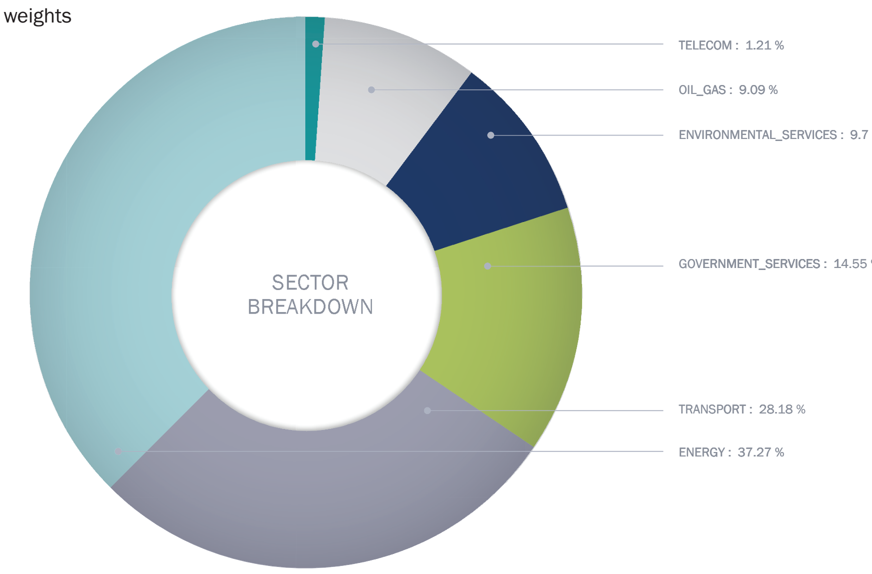
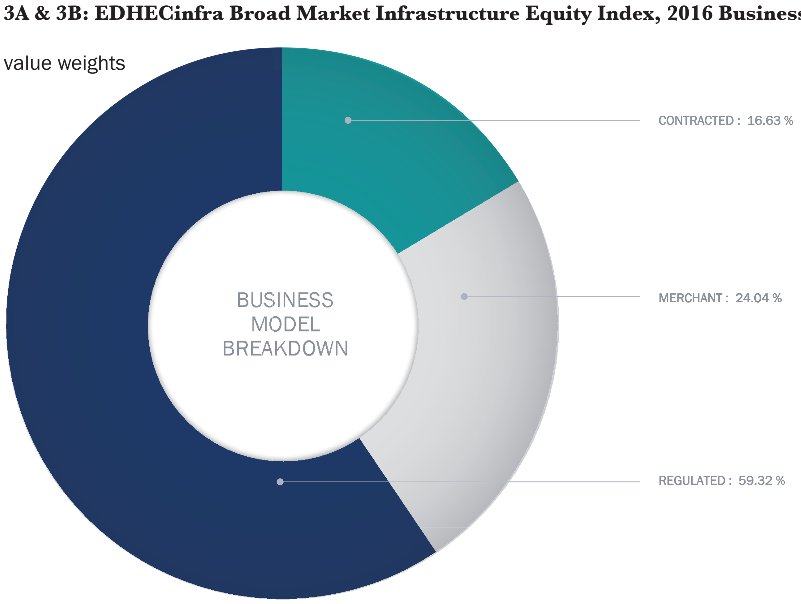


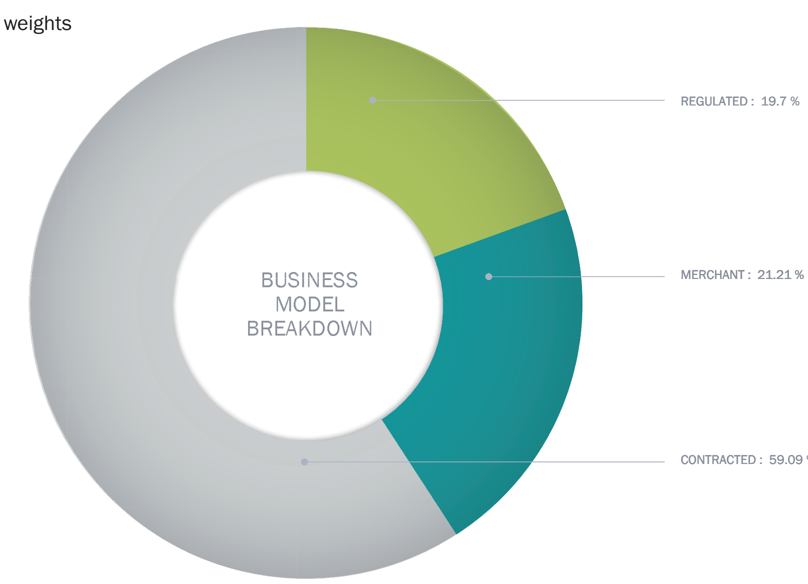
EXHIBIT 3

3A & 3B: EDHECinfra Broad Market Infrastructure Equity Index, 2016 Business Model Breakdown by Market Value

value weights



equal weights



Private infrastructure equity investments outperform the market …

A number of stylized facts can be drawn with respect to our first two questions about the risk-adjusted performance of private infrastructure equity:

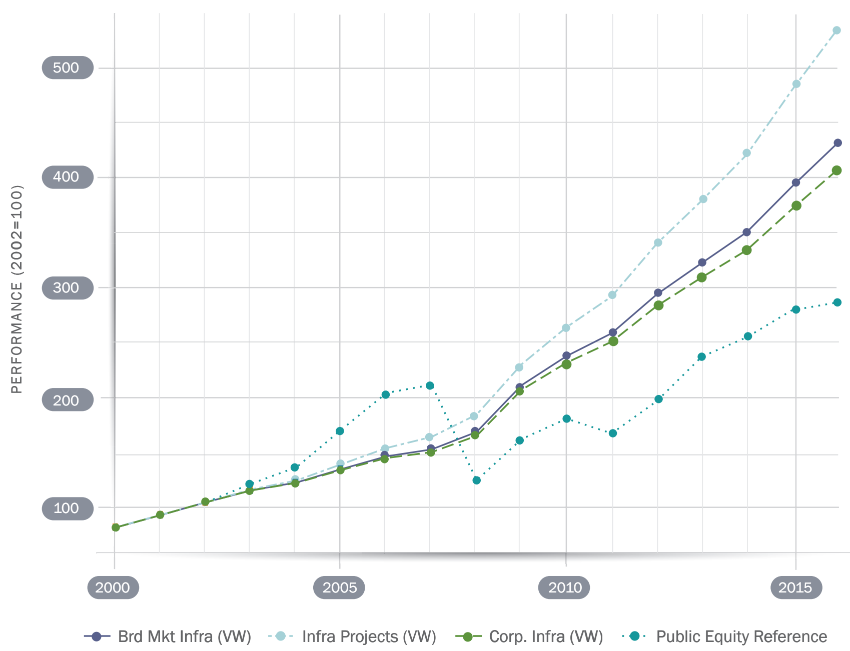
- Our broad European market infrastructure equity index (including project and infrastructure corporates) significantly outperforms the European public equity reference index over the 2000-2016 period.
- It also does not suffer from any drawdown during the 2007-2008 and 2010-2011 periods of stock market collapse, as shown in figure 4.
- Figure 4a shows that it is infrastructure projects, rather than corporate, that contribute most of the broad market performance.
- Figure 4b suggests that merchant and contracted infrastructure contributed equally to this outperformance. However, this is shown on a value-weighted basis, which tends to overweight larger projects. We note that on an equally weighted basis (not shown here), most of the outperformance comes from contracted infrastructure alone.
- Looking at IRRs in figure 5, a secular trend of lower IRRs is visible, driven by higher equity valuations of private infrastructure firms over the period. We note that infrastructure projects have significantly higher IRRs than infrastructure corporates (figure 5a) and that merchant infrastructure also tends to have higher IRRs than contracted or regulated infrastructure (figure 5b).
- We also note that broad market IRRs have breached an 8% floor, which is also the hurdle rate of numerous private-equity funds, suggesting that such investment vehicles either need to re-assess their hurdle rates or cannot continue to operate in the current infrastructure valuation environment.

Tables 1 and 2 provide more details about the risk-

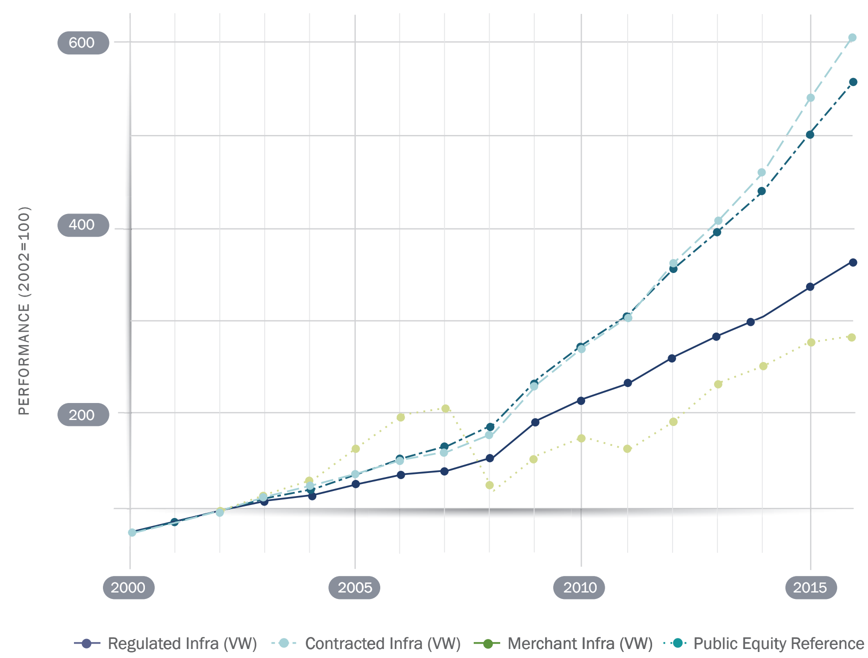
EXHIBIT 4

4A & 4B: EDHECinfra Equity Indexes, Cumulative Performance, Value-Weighted, 2000-2016

broad market and by corporate structure



by business models



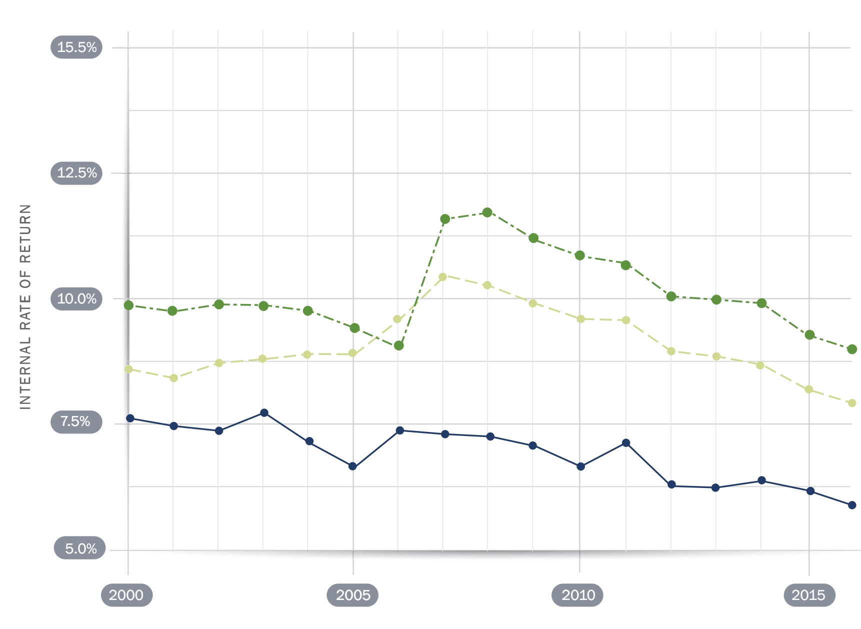
Note: Public equity reference: Scientific Beta Developed Cap-Weighted index

EXHIBIT 5

EDHECinfra Equity Indexes, Internal Rate of Return, 2000-2016

broad market and by corporate structure

by business models



adjusted performance of private infrastructure equity for projects and corporates at different horizons, on a value-weighted and equally weighted basis, respectively.

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

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

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

…but achieving sufficient diversification is what investors should be focusing on

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

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

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

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

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

Exhibit 6 shows the distribution of asset-level return volatilities over the entire observation period. Our asset-level volatilities are not "smoothed"[4] and can in fact be quite high, sometimes higher than 100%. Indeed, one of the results of our cash-flow modeling and forecasting for equity investors is that equity payouts are quite variable both in size and frequency.

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

Exhibit 7 shows the relationship between the "effective number of bets," or ENB[5], of each of the 192 EDHECinfra private infrastructure equity indexes in 2016, and the standard "portfolio risk measure" of each index, which combines the weighted return volatility of each index constituent with a pair-wise covariance matrix of asset returns.

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

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

We note that substantial risk reduction appears beyond 50 constituents, a number of assets that few infrastructure asset owners or managers can hope to achieve today. Indeed, achieving such levels of portfolio diversification is a genuine challenge for infrastructure investors today. Building a large portfolio of infrastructure assets requires a large budget and many years. Moreover, investing on an equally weighted basis, let alone using a more risk-efficient weighing scheme,

TABLE 1

Private Infrastructure Equity Key Metrics, Broad Market, Projects and Infrastructure Corporates, Europe (14), Fully Hedged, Value-Weighted

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

A. Broad Market

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

B.Infrastructure Projects

	1-year	3-year	5-year	10-year	Hist
Return	11.57%	12.31%	13.11%	13.71%	12.65%
Volatility	5.19%	5.23%	5.32%	5.37%	6.67%
Sharpe Ratio	2.59	2.65	2.72	2.61	2.06
Max Drawdown	0%	0%	0%	0%	0%

C. Infrastructure Corporates

	1-year	3-year	5-year	10-year	Hist
Return	9.72%	9.76%	10.41%	11.35%	10.81%
Volatility	11.42%	10.73%	10.73%	11.34%	12.71%
Sharpe Ratio	1.01	1.05	1.1	1.03	0.87
Max Drawdown	0%	0%	0%	0%	0%

D.Public Equity Market Index Reference

	1-year	3-year	5-year	10-year	Hist
Return	2.62%	6.73%	11.96%	5.72%	9.59%
Volatility	11.84%	13.19%	11.98%	15.19%	14.08%
Sharpe Ratio	0.38	0.63	1.11	.041	0.68
Max Drawdown	0%	0%	0%	42.5%	42.5%

TABLE 2

Private Infrastructure Equity Key Metrics, Broad Market, Projects and Infrastructure Corporates, Europe (14), Fully Hedged, Equally-Weighted

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

A. Broad Market

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

B.Infrastructure Projects

	1-year	3-year	5-year	10-year	Hist
Return	13.43%	14.32%	15.02%	15.39%	14.33%
Volatility	4.16%	4.18%	4.21%	4.3%	4.72%
Sharpe Ratio	3.68	3.8	3.88	3.7	3.13
Max Drawdown	0%	0%	0%	0%	0%

C. Infrastructure Corporates

	1-year	3-year	5-year	10-year	Hist
Return	10.27%	10.72%	11.37%	12.34%	11.9%
Volatility	6.39%	6.31%	6.29%	6.26%	7.02%
Sharpe Ratio	1.9	1.95	2.02	2.04	1.74
Max Drawdown	0%	0%	0%	0%	0%

D.Public Equity Market Index Reference

	1-year	3-year	5-year	10-year	Hist
Return	2.66%	8.21%	14.41%	7.36%	12.29%
Volatility	13.25%	13.27%	12.39%	16.71%	15.5%
Sharpe Ratio	0.34	0.74	1.27	.047	0.79
Max Drawdown	0%	0%	0%	47.82%	47.82%

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

[5] *A measure of portfolio concentration equal to the inverse of the Herfindahl-Hirschman Index, i.e., the sum of squared weights (see Meucci, Santangelo, and Deguest, 2013).*

is virtually impossible given the discrepancy between the illiquidity of individual constituents and the rebalancing requirements of equally weighted schemes.

Still, these results show that achieving only limited levels of portfolio diversification is not a benign problem for investors. The opportunity cost of the low diversification in infrastructure equity portfolios may in fact be very large.
In the absence of well-diversified infrastructure products, most infrastructure investments become very active, concentrated bets, and it becomes much more difficult for investors to have a view on infrastructure investment at the asset allocation level.

Tomorrow: the need for investible solutions

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

These results allow asset owners and managers to begin to evaluate how they might better access infrastructure investments, so that infrastructure investing can become a means to an end and help them meet their investment goals in a more meaningful manner.

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

But the large and illiquid nature of these investments also creates a diversification challenge within the asset class. In effect, the coveted investment narrative, which our broad market indexes confirm the existence of, may seem slightly out of reach to most investors if it means being exposed to hundreds of infrastructure assets.

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

Full results for 192 indexes can be seen at https://benchmarks.infrastructure.institute/equity/
You can download index factsheets, price, return and constituent data.

EXHIBIT6

Density Plot of Asset-Level and Index-Level Volatilities 192 EDHECinfra Equity Indexes, 2000-2016
Distribution of index−level and asset−level return volatility measures, 2000−2016

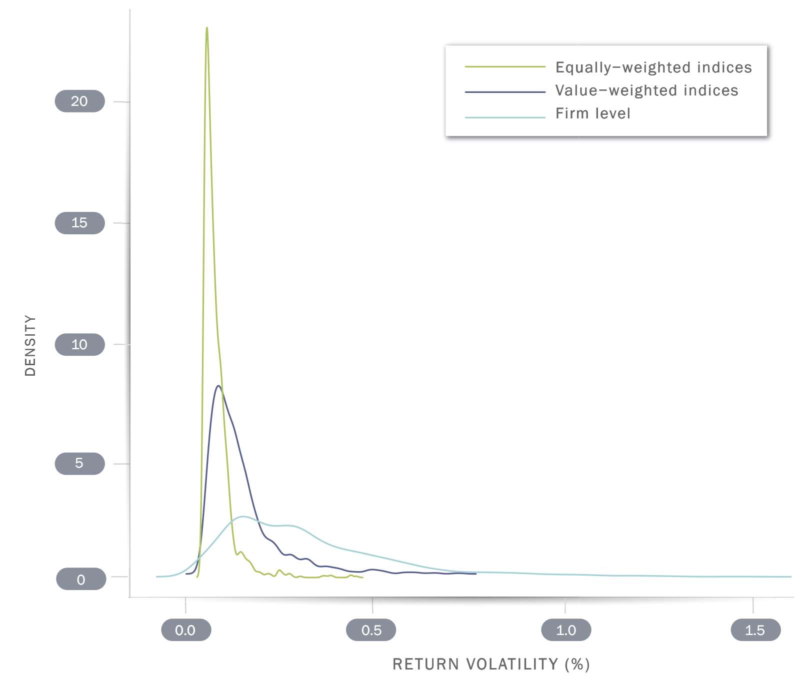
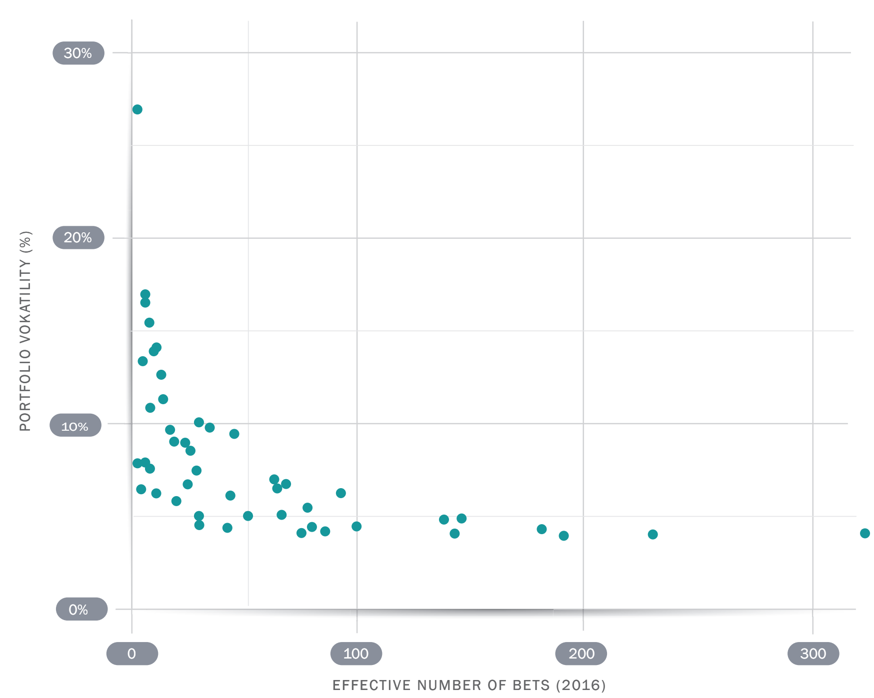


EXHIBIT 7

Effective Number of Bets and Portfolio Risk Measure in 192 EDHECinfra Equity Indexes, 2016



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INDEXES

Private Infrastructure Debt Benchmarks

Project finance debt is a star performer, but are 'infrastructure corporates' #fakeInfra?

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In a new paper drawn from the work of the EDHEC/NATIXIS research chair, we present the first results of a multi-year project to create and compute fully fledged private infrastructure debt investment benchmarks.

As is the case for the equity indexes presented in the previous article, the first version of these indexes span 14 European countries over 16 years, going back to the year 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 this paper, we focus on what distinguishes infrastructure debt from corporate debt and use the EDHECinfra 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 sub-indexes contribute to the performance of a broad market infrastructure debt index?

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

1. The first view equates infrastructure investment with "project finance"[6] and echoes the June 2016 advice of the European insurance regulator 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 "infra structure corporates" in the definition of qualifying infra structure 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.

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

Our data collection approach follows a similar approach to that described for creating equity indexes. 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.

While this is more difficult and resource intensive, it avoids a frequent problem found in research using private data: multiple biases created by the sources of 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 investible universe for which data can be collected.

In the investible 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 EDHECinfra template, we collect data about each firm and each debt instrument identified as part of its capital structure. This data is collected from multiple sources and aggregated, cross-referenced, analyzed and validated by a team of human analysts. Each firm's data is reviewed iteratively at five 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 information available about each senior debt instrument present in the firm's capital structure.
2. The mean and variance of the firm's debt service cover ratio (DSCR) are estimated for each firm in all realized periods and forecasted for the remainder of the firm's debt maturity.
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.
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.
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, and 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.
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 sub-index) and individual assets are aggregated following certain inclusion and re-balancing rules.

Three key indexes

While the available segmentation options of our indexes allow 192 different combinations of the European infrastructure debt market billionto be computed, to answer the two questions above, we focus on the following three key indexes for the 2000-2016 period:

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 capitalization of EUR 106.1 billion. 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 capitalization of EUR 48.7bn, 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 EUR 57.4 billion capitalization 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 a restructuring event. Debt refinancing or successful restructuring events (workouts) lead to the creation of new instruments and the 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.

Exhibits 1-3 show the composition of the Broad Market Infrastructure Equity Index by country, sector and business model, on a value-weighted and equally weighted basis.

Infrastructure debt is unique …

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

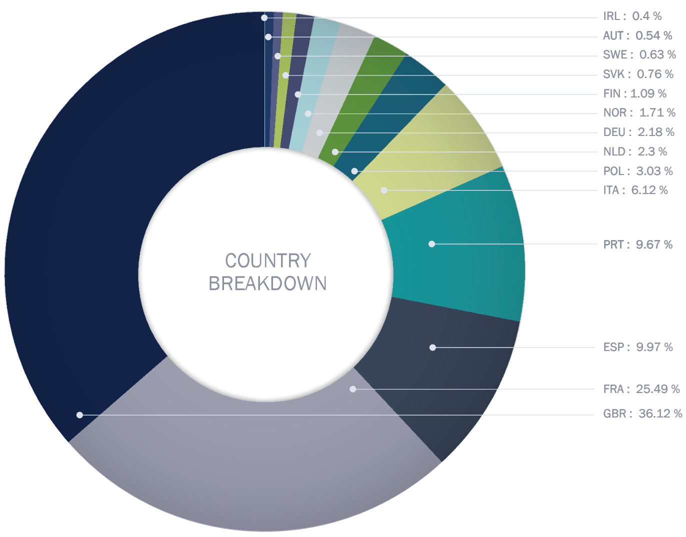
1. The broad European market infrastructure debt index (including project and infrastructure corporate debt) significantly outperforms the European corporate bond debt index over the 2000-2016 period, thanks to a significant yield spread.
2. On a value-weighted basis, the broad market infrastructure debt index exhibits significant concentration, and its Sharpe ratio or risk-adjusted performance is not significantly different from that of the corporate bond index, as evidenced by the results in table 1.
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.

[6] *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).*

EXHIBIT 1

1A & 1B: EDHECinfra Broad Market Infrastructure Debt Index, 2016 Country Breakdown by Market Value

value weights



equal weights

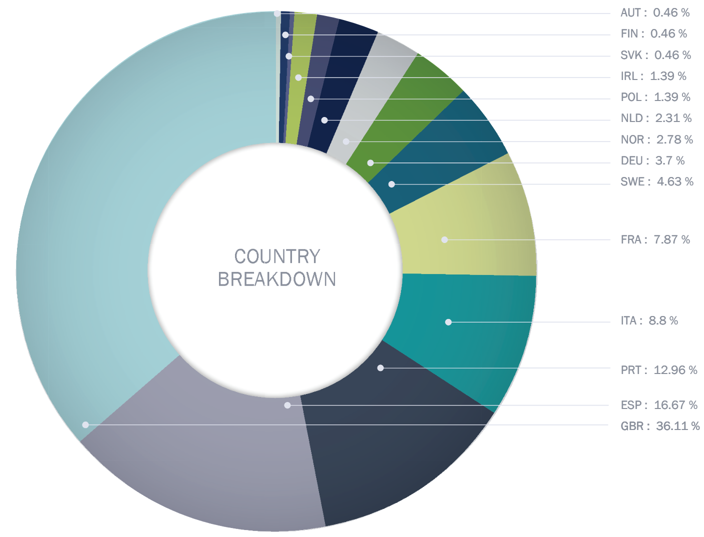
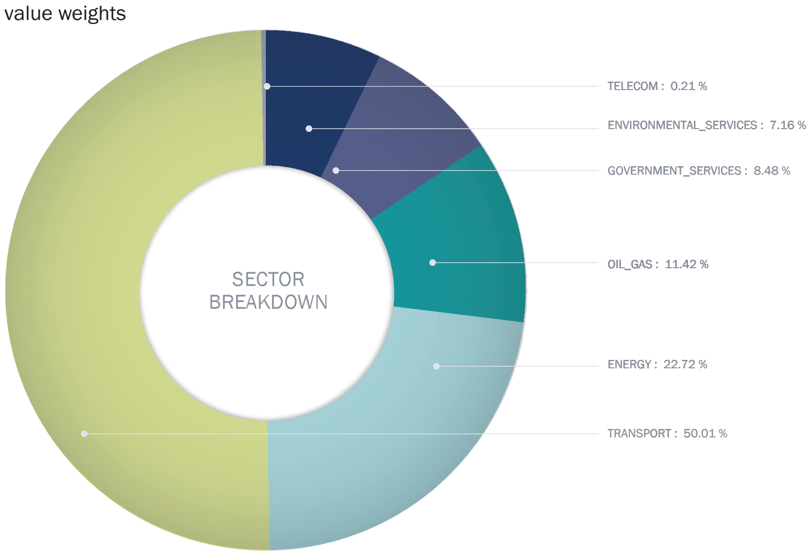


EXHIBIT 2

2A & 2B: EDHECinfra Broad Market Infrastructure Debt Index, 2016 Sector Breakdown by Market Value

value weights



equal weights

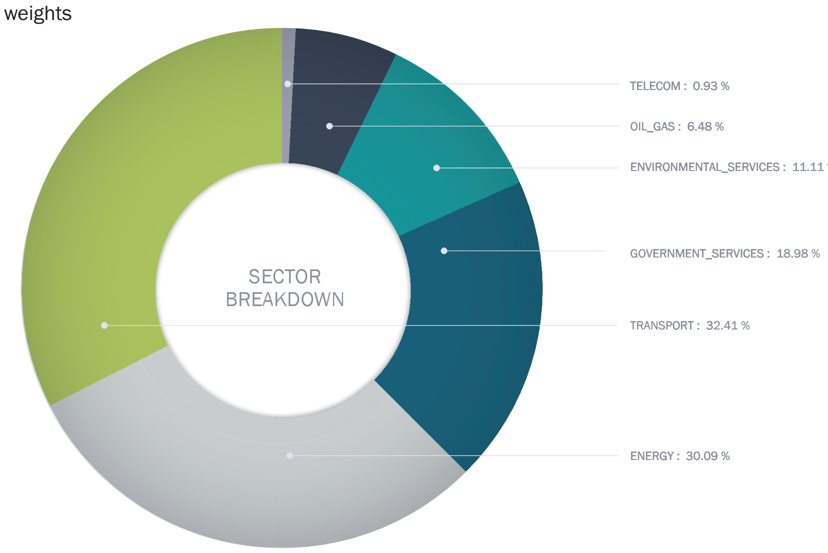
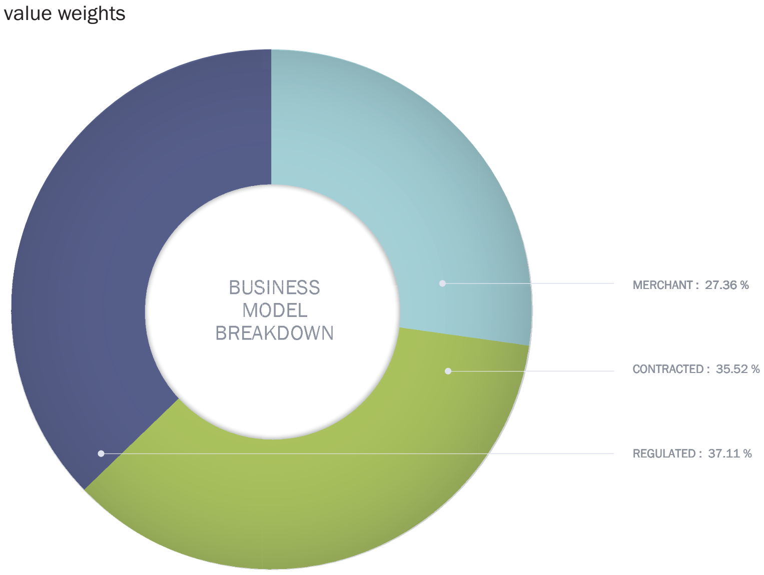


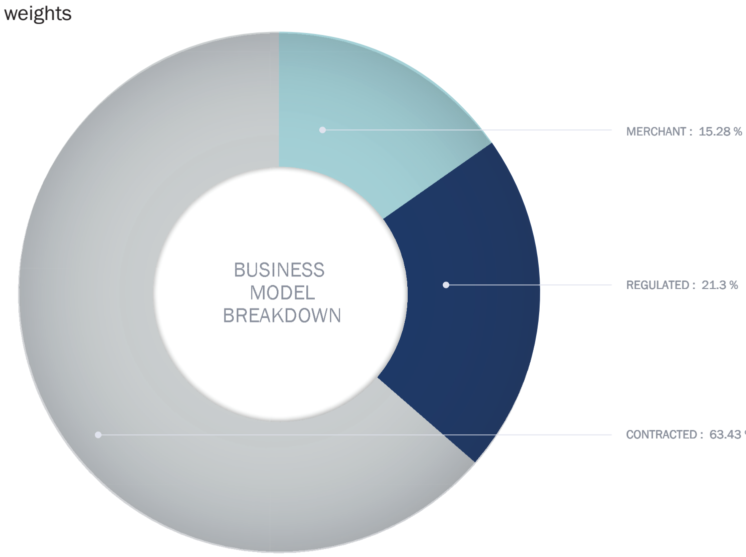
EXHIBIT 3

3A & 3B: EDHECinfra Broad Market Infrastructure Debt Index, 2016 Country Breakdown by Market Value

value weights



equal weights



4. The duration and value-at-risk (figure 6) 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 behavior of the two sub-indexes that make up this broad-market measure allows a more granular understanding.

… but project finance and infrastructure corporate debt are different

1. The infrastructure project finance senior debt index does not deliver better cumulative outperformance than the broad market infrastructure debt index over the entire period, as figure 4 shows.
2. Still, its yield spread, shown in figure 5, 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 (see table 1).
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:

1. The infrastructure corporates senior debt index delivers 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 indexes considered.

Is corporate infrastructure debt #fakeInfra?

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.

n 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. •

EXHIBIT 4

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

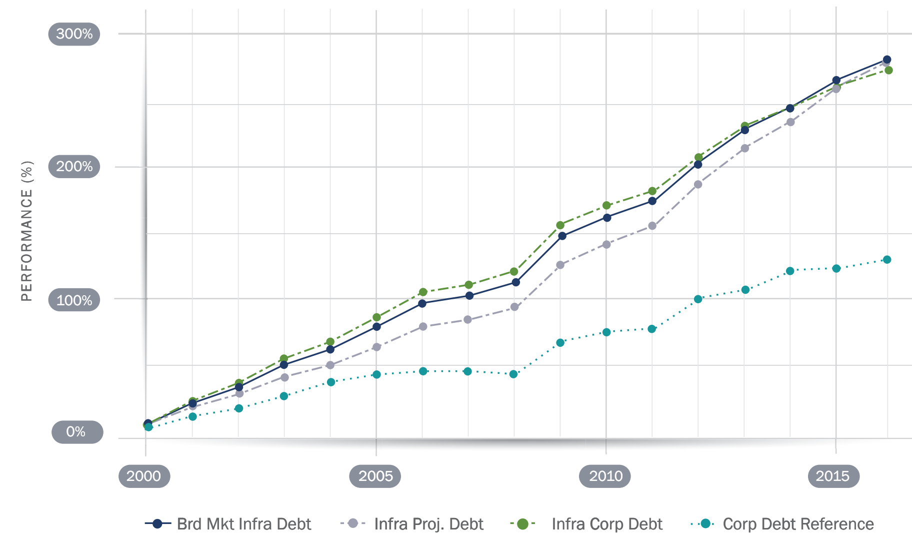


EXHIBIT 5

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

EXHIBIT 4

Value-at-Risk: Value-weighted senior private infrastructure debt indexes, Europe (14), fully hedged, 2000-2016

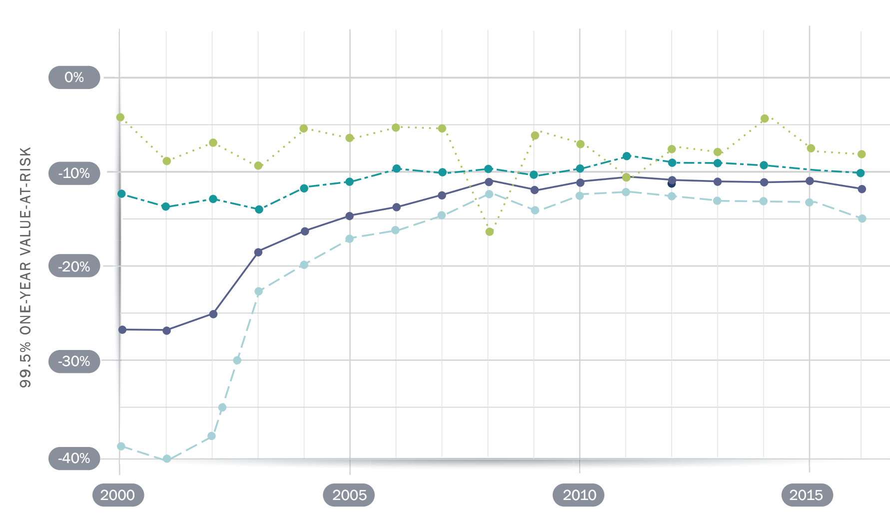


TABLE 1

Private Infrastructure Debt Key Metrics, Broad Market, Projects and Infrastructure Corporates, Europe (14), Fully Hedged, Value-Weighted

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 indexes.

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 Projects

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	2.28	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 Equity Market Index Reference

	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%

We conclude that while infrastructure project finance debt has a unique risk-reward profile, infrastructure corporates probably cannot qualify as a new asset class.

INDEXES

The Valuation of Private Assets

Frederic Blanc-Brude
Director, EDHEC Infrastructure Institute

Asset owners are winning the argument to lower private-equity manager fees, their next battle will be about the valuation of private assets.

Private-equity funds have long been characterized by high fees. Even as the number of asset managers (general partners, or GPs) offering PE funds increased steadily over the past decades, competition for the attention of limited partners (LPs) did not lead to an immediate shift in the cost of mandating specialist managers to buy and sell private companies.

In recent years, pressure from asset owners has led to a seemingly ineluctable trend toward fewer and lower private-equity management fees.

The fact that increasing competition did not immediately lead to lower costs, when these were high to begin with, is an interesting puzzle. Economists would see a case of strong information asymmetry between buyers and sellers, combined with a case of "type pooling;" that is, in a market where some managers are capable of delivering a high-quality service at a fair price (type A) but most are not (type B), both types of manager can tend to "pool" together and offer the same low-quality product at a high price. Competition fails. This common phenomenon (think "finding a good plumber") is the result of information asymmetry: clients cannot tell beforehand which service providers are of type A or type B.

Fee levels are only a consequence, or a symptom, of information asymmetry between GPs and LPs.

High fees had so far been acceptable to LPs because of high reported returns. But as the recent decisions by CalPERS or NYCERS to pull out of hedge funds altogether illustrate, lower returns in recent years have made fee levels much harder to justify in alternative strategies.

In turn, reported excess returns in hedge funds or private real estate are lower in part because they are better measured: valuation methodologies and available data have improved sufficiently to allow quasi-market valuations to be reported. Hence, outperformance measurement has become more accurate, and also lower because a greater proportion of hedge fund or private real estate performance can now be understood as a combination of market betas and not the result of pure investment skills.

The evolution of asset pricing techniques and better data availability have led to more accurate risk-adjusted performance measurement and to a reevaluation of the benefits received by LPs from delegating investment decisions to a hedge fund or private real estate manager.

In other areas of the alternative universe, private asset valuation remains a source of significant information asymmetry between GPs and LPs. For very illiquid and thinly traded assets, such as infrastructure, investments returns continue for the most part to be reported on the basis of quarterly or annual appraisals, which leads to a number of well-known issues: stale pricing, return smoothing and the impossibility to estimate the true diversification contribution of such assets in the absence of reliable measures of co-variance.

When assets are valued by discounting 25 years of future cash flows, the choice of cash flow scenario and discount factors explains most of the reported performance. In the absence of robust cash flow forecasting and discounting techniques grounded in financial theory, the entire reporting exercise amounts to a set of ad hoc and often opaque assumptions.

Nor is this news to asset owners. In the 2016 EDHEC Infrastructure Institute/Global Infrastructure Hub survey of institutional investors' perceptions and expectations of infrastructure investment, fewer than half of respondents declare that they trust the valuation reported by private infrastructure asset managers. A quarter declared that they do not know whether they can trust them or not, and a little more than a quarter bluntly report that they do not trust reported NAVs in infrastructure PE funds (see Blanc-Brude et al., 2016).

Today, in the infrastructure and other very illiquid asset classes, reported returns are also somewhat lower because new investments are being made at higher prices, and the pressure from LPs to lower fees is on.

But bludgeoning service providers into charging lower fees (sometimes with the help of the regulator) without asking them to provide better service does not solve the market failure identified above.

Those who pull out of delegated investment can either abandon an asset class altogether (no more hedge funds!) or try to internalize the skill set. But in both cases, this creates opportunity costs from lower diversification with and within the asset class (you cannot replace 20 asset managers with one internal team). In the latter case, it also creates direct costs.

Furthermore, private investment teams operating within asset owners still mostly report the same stale NAVs and IRRs, while those who stick with private asset managers who can only charge low fees (because the regulator said so) may now be faced with 100% of type Bs.

So are asset owners condemned to maneuvering between the Scylla of DIY private investing and the Charybdis of opaque and expensive delegated investment in private assets?

There are solutions to minimize the effect of information asymmetry in market dynamics. To avoid the pooling of manager types, market participants can create "sorting devices" (Spence, 1973; Rothschild, 1992) or "revelation mechanisms" (Laffont and Martimort, 2002) to facilitate the processing of information from uninformed to informed participants.

In economics, this problem is typically modeled as a "market with adverse selection and competitive search," where some agents post terms of trade (term sheets) and others aim to screen the other side of the trade by agent type (Guerrieri, 2010). In such models, the informed side of the trade (here the asset manager) can move first and signal to the market what terms they can offer, or the uninformed side (asset owners) can move first and request bids for a discriminating "menu" of potential products or investment solutions, which includes items that only type A managers can deliver, prompting type Bs to exit this segment of the market.

Hence, beyond the debate on fees, the need to better discriminate between private asset managers should lead asset owners to require better reporting, better valuation techniques and better risk-adjusted performance measurement.

Their next battle will logically be to improve the valuation framework of private assets and move away from reporting single IRRs and toward a fully fledged factor decomposition of returns. In fact, CalPERS did keep one hedge fund manager on its books, the only one that could offer a hedge fund strategy defined in terms of alternative betas.

Still, it should be noted that solutions to problems of information asymmetry always involve the uninformed side paying an "information rent" to the informed side for revealing its type. In other words, asset owners should not expect to get type A managers on the cheap. Still, it remains in their best interest to try and discriminate between them and the rest, because it can lead to the cheapest outcome for a given level of risk-adjusted performance.

Finally, given the recent trend on fee levels in private equity, it is also in the best interest of type A managers to signal very clearly that they can deliver better measured outperformance by adopting more transparent and useful performance reporting standards, and valuation methodologies that are better adapted to the nature of the information available about private assets.

In the next article in this supplement, we detail our approach to private equity and debt valuation used to build the infrastructure investment benchmarks created by EDHECinfra.

Thanks to these indexes and the transparent techniques and data reporting standards put forward by EDHECinfra, asset owners will not be obliged to do away with delegated investment management altogether, but can hope to be better able to find type A asset managers and to expect them to achieve what the type B simply cannot deliver. •

asset owners' next battle will be to improve the valuation framework of private assets and move away from reporting single IRRs and toward a fully fledged factor decomposition of returns.

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INDEXES

How to Derive Equity and Debt Index Results

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In this article, we provide an overview of the technology used to derive the equity and debt index results presented in the previous articles. 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 or equity are seldom traded, and only a limited amount of market-price data is observable. Hence, the risk-adjusted performance of each firm in the index sample is derived by forecasting cash flows to each firm's creditors or owners (including any shareholder loans and other payouts other than dividends), and discounting them according to the duration and volatility of future payouts and prevailing market conditions. A term structure of discount rates is thus inferred from observed market prices, including the initial value of the investment and comparable transactions taking place each year.

Once each firm's equity or senior debt 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 first requirement is a combination of expected payouts to debt or equity holders and of the conditional (future) volatility of these payouts at each future point in the life of the investment.
2. In the case of equity payouts, we proceed in the following manner:
   - A model of the "free cash flow to equity" (FCFE) until the end of the investment life is implemented using information about the firm's revenues, capital and operating costs, as well as its capital structure, debt service cover ratio and forecast debt service.
   - The mean and variance of each firm's FCFE "retention rate" (RR. i.e.. Cash at Bank end of period/ FCFE) is estimated in all realized periods and a forecast is made for the remainder of the firm's life.
   - The combination of the forecast of the mean and variance of FCFE and RR allows computing a stream of expected equity payouts as well as their conditional volatility.
3. In the case of senior infrastructure debt, we apply the following approach:
   - 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.
   - The mean and variance of the firm's debt service cover ratio (DSCR) are estimated for each firm in all realized periods and forecasted for the remainder of the firm's debt maturity.
   - 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.
4. Firms or debt instruments are then grouped by risk "clusters," or buckets, as a function of their payout volatility and time-to-maturity in each period, i.e., debt or equity stakes, are grouped by families of payout risk and duration.
5. Observable market prices (new and secondary market transactions) in each year are used to estimate a risk premium as a function of observable characteristics of firms, such as risk cluster, duration, and cash flow volatility, and the estimated relation between risk premium 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.
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 sub-index) and individual assets are aggregated following certain inclusion and re-balancing rules.

Cash flows

Blanc-Brude, Hasan and Ismail (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.

On the equity side, we rely on two key inputs: a free cash flow to equity measure and forecast in combination with a FCFE retention ratio. These two quantities are always observable and much better behaved statistically.

In the following sections, we summarize the approach taken to obtain these two types of inputs for each firm in the index sample.

Future debt service and free cash flow to equity

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;
2. Computation using individual debt instruments' attributes (outstanding principal, interest rate, maturity date and amortization profile) collected from contributors or audited accounts;
3. Estimation using Bayesian inference after four or five years of observed principal and interest payments, and other available information about the firm in question (e.g., average "tail" length[7] 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 amortization profiles used in similar transactions, etc. (see Hasan and Blanc-Brude, 2017a, for more details)

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.).

The future Free Cash Flow to Equity of each firm, defined as

$$FCFE_t = CFADS_t - DS_t$$

where DS_t is the senior debt service owned at time t and $CFADS_t$ is the cash flow available for debt service (the free cash flow) at time t, is obtained from private contributor data and computed using individual firms' audited accounts. It is then the object of a forecast for the remainder of the firm's life, using a state-space estimation technique described below, and controlling for the future debt service.

Once we have the future debt service and future free cash flow to equity of each firm, we need to estimate the dynamics of two key ratios: the debt service cover ratio and the FCFE retention rate.

DSCR mean and volatility

To understand private infrastructure debt, 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:

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

where C_{bank}, C_{op}, C_{IA}, C_{dd} and 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, Hasan, and Whittaker, 2016, for a more detailed discussion of how DSCRs can be computed).

We call this ratio the "economic" DSCR because it encapsulates the economic capacity of the creditor firm to repay its debt: as soon as this ratio equals 1, the firm is on the brink of default.

Free cash flow to equity and retention rate

On the equity side, observing equity and quasi-equity payouts does not necessarily allow for very robust modeling at the firm level because private firms tends to have a more erratic dividend payout behavior than listed firms. Equity payouts can vary considerably in size and frequency and make direct statistical modeling unreliable. Instead, we apply a similar approach to the one taken observing and modeling cash flows on the debt side, and The FCFE retention rate (RR) is computed as

$$RR_t = \frac{Cash@Bank_t}{FCFE_t}$$

Where $Cash@Bank_t$ is all cash held at bank at the end of each period and $FCFE_t$ is the free cash flow to equity as defined above.

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

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

RR and DSCR state estimation

In a first step, the mean μ and variance σ^2 parameters

[7] Loan tail in project finance: the number of years beyond loan maturity during which the project is still operational.a power plant).

(or state) of the DSCR or RR process have to be inferred from observable data. Since between four and 20 years of realized 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: $x_t=f_t.x_{t-1}+\epsilon_t$ (state equation) $y_t=g_t.x_t+\eta_t$ (observation equation) where x_t is the unobserved state of the system at time t, y_t is the RR or 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.

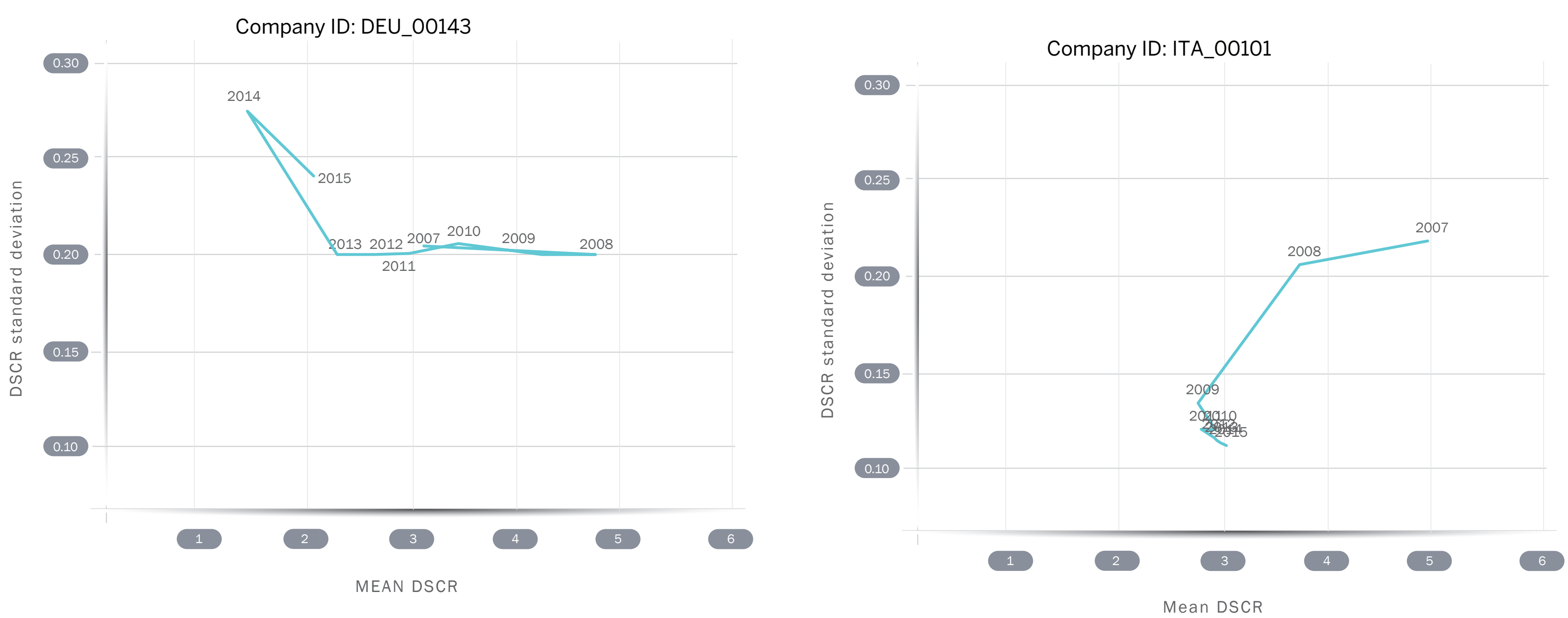
With each RR or DSCR observation, the true value of the mean and variance parameters of each firm's RR or DSCR and their evolution in time is "learned" — just like a self-driving car continuously reassesses its coordinates in an (x,y) plane, we continuously reassess the position of the RR or DSCR process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

Exhibits 1 and 2 illustrate this process for example project companies in Italy, Germany, the U.K. and Portugal: the time t value of the RR or DSCR mean and variance is predicted at time $t-1$ and effectively tracks the realized RR or

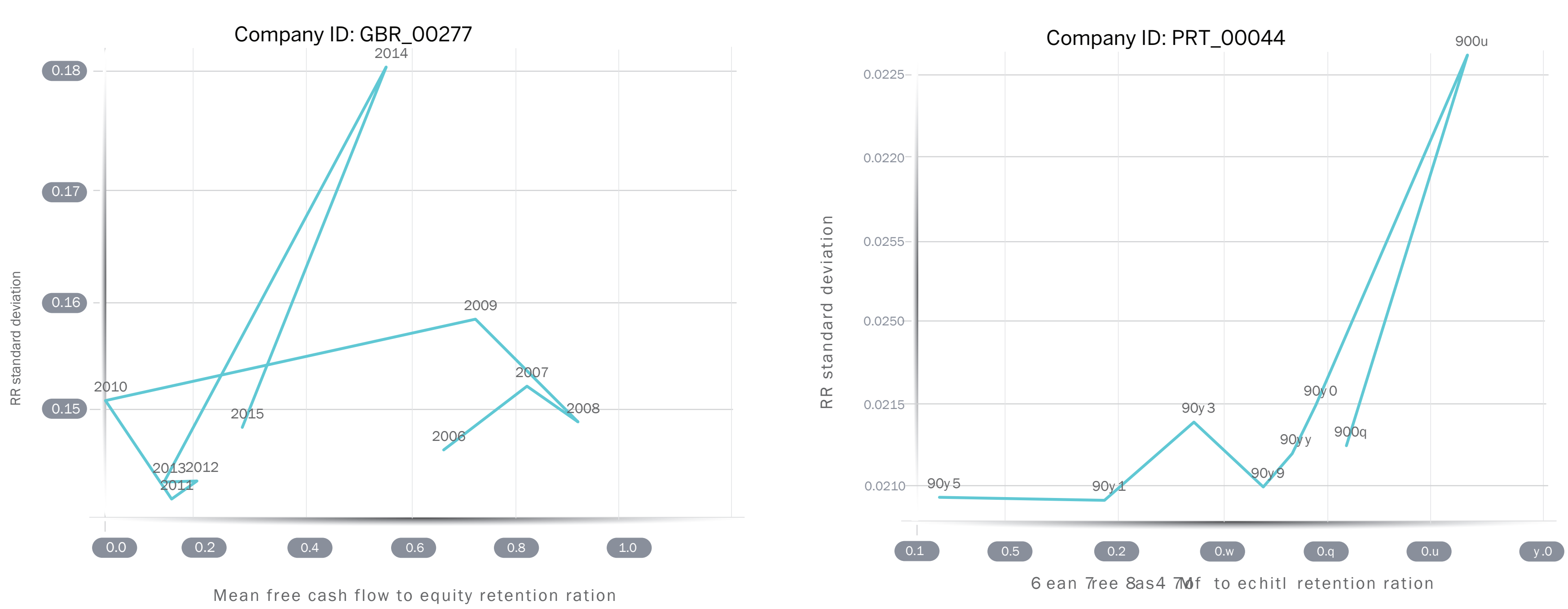
EXHIBIT 1

Filtered mean and variance trajectory of the RRt and DSCRt in example projects

DSCR trajectories



RR trajectories



DSCR value at time .RR and DSCR forecasting

Once the parameters of the DSCR distribution of each firm have been derived for realized time periods, we use these estimates to derive a forecast of the mean and variance of the firm's RR or 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).

In view of the Markovian (autoregressive) nature of the state space model, the recursive formulas of the mean and variance of the firm's RR or 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^2 at time t act like an initial distribution (prior) of the future evolution of the model, which provides a summary of available data that is sufficient for predictive purposes.

Hence, the corresponding posterior distribution contains all the information about the future provided by the available data. As k becomes larger, depending on the corporate structure and business model of the firm, uncertainty increases in the system, and the forecasts of the future true values of 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. Next, on the debt side, one extra step is required to take into account the possibility of default and recovery in senior debt investments.

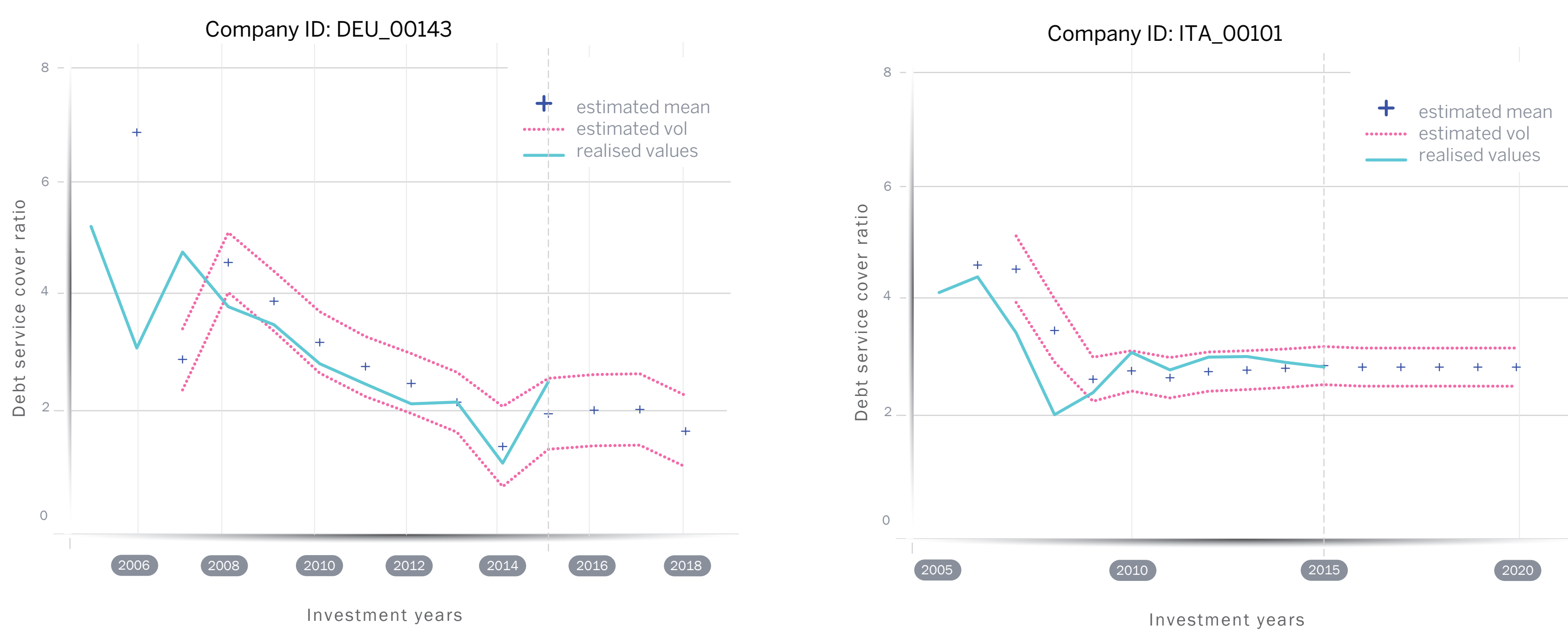
Credit risk

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

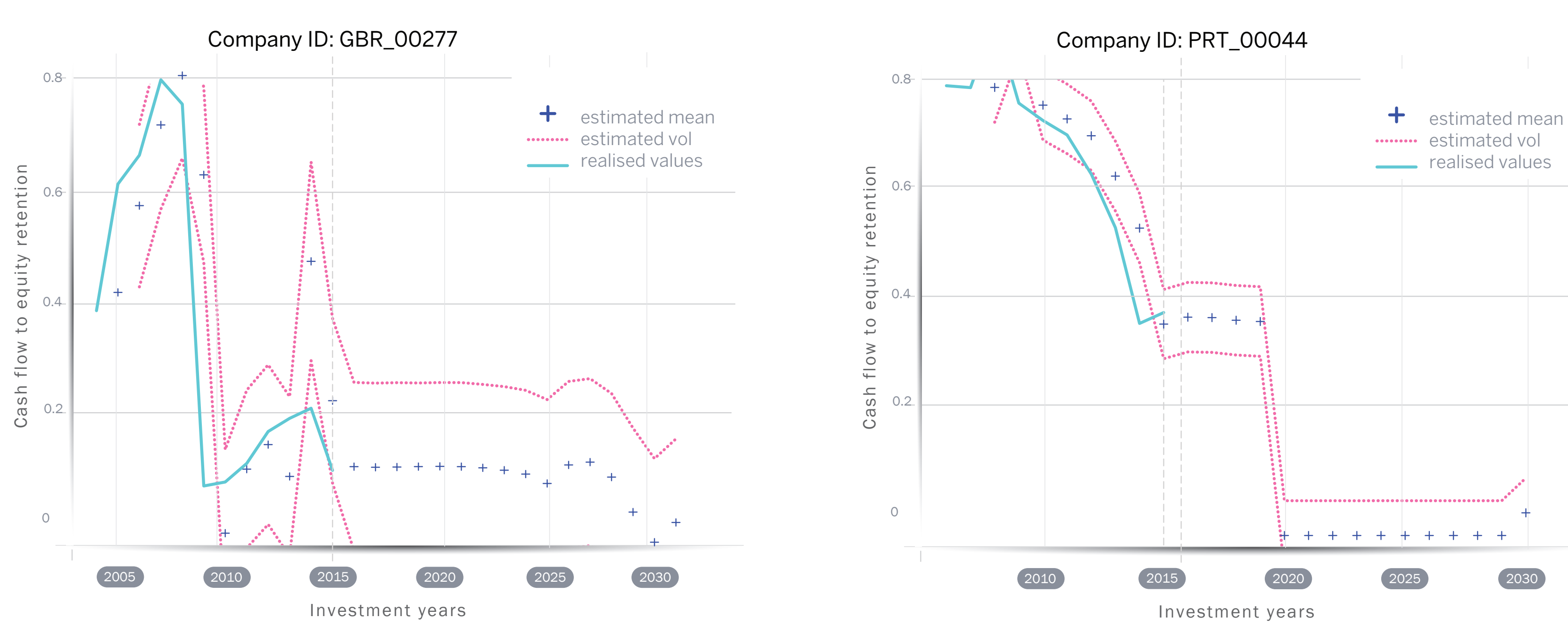
EXHIBIT 2

Estimation of the true mean and variance, and forecast of RR and DSCR

DSCR trajectories



RR trajectories



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:

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

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:

$$CFADS_t = DSCR_t \times DS^{BC}_t$$

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,[8] 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.

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 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 maximize the expected value (or minimize 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.

Asset pricing

Risk buckets

Next, once a RR or 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 RR_t or $DSCR_t$), 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.[9]

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 sub-indexes, but hierarchical clustering allows the derivation of more robust pricing measures and covariance estimates.

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

Exhibit 3 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.

Discount factors

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

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

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

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

where $r_{i,t+1}$ is the return on i^{th} asset, $r_{f,t+1}$ is the return on a risk-free asset, $\beta_{Fk,t+1|t}$ is the asset's exposure to k^{th} risk factor, and $E_t(r_{k,t+1} - r_{f,t+1})$ 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:

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

EXHIBIT 3

Grouping of assets by business model families vs. volatility and Duration hierarchical clusters

[8] 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.

[9] Still, the heterogeneity of investor preferences with regard 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).

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,

$$\frac{(r_{F,t+1|t} - r_{f,t+1})}{\sigma_{F,t+1|t}},$$

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:

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

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 to 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, private infrastructure equity or 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 summarized 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 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" 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, Piazzesi, and Wei (2006). Then, we collect observable risk premia information for senior loans and bonds (i.e., available market price data). These spreads can then be expressed in terms of risk premia as:

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

where $spread_{i,t}$ is the observed premium on the i^{th} loan, $\lambda_{k,t}$ is the price of k^{th} risk exposure, and $\sigma_{k,t}$ is the size of the k^{th} exposure. The different risk exposures that we consider include cash flow risk, as measured by the "cluster" to which the project belongs; 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 minimizing errors between observed spreads and model-implied spreads, so that:

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

This allows us to estimate 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 re-compute current spreads for all live instruments, combining information about the current risk profile of each instrument (the latest iteration of the Retention rate or debt service cover ratio state and forecasting models) and prevailing market conditions.

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

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

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

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 ratio, value-at-risk, duration, etc.

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:

$$R_P = \mathbf{w}'\mathbf{R}$$
$$\sigma_P^2 = var(\mathbf{w}'\mathbf{R}) = \mathbf{w}'\Sigma\mathbf{w}$$

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 always dimensionality. That is, estimating the covariance matrix of a portfolio made of a large number of assets is subject to a lot of noise or the "curse of dimensionality" (Amenc et al., 2010), where each 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 investments are unknown *ex ante*. Indeed, they are what we set out to discover. Hence, our approach to group assets by "risk buckets" (defined as statistical clusters of volatility and duration) aims to capture persistent but unknown combinations of priced risk factors.

Once covariance is known within each cluster, the covariance matrix can be written as the combination of intercluster and intracluster covariances and estimated in any given year for the main index or any sub-index 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:

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

One advantage to 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.

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 sub-index constituent is readily known and the relevant index covariance matrix can be derived.

PORTFOLIO RULES

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

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

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

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

Value weighting is a standard way to proxy the "market" but it overweights the largest firm and/or the most indebted issuers and increases risk and issuer concentration. This could be a particular concern in the case of broad market infrastructure indexes, since very large firms and 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 firms or debt issuers.

Equal weighting thus represents a simple yet intuitive way to consider the contribution of all index constituents by maximizing 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 indexes, index weighting schemes are associated with rebalancing decisions requiring buying and selling. In the case of highly illiquid private infrastructure investments, such rebalancing decisions are not possible. In practice, a direct investor or manager in private infrastructure equity or debt cannot easily or speedily adjust their ownership of any given firm or its debt.

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 indexes 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 investible 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.[10]

On the debt side, three simple portfolio-inclusion rules are implemented to avoid unnecessary noise/distortion of reported performance:[11]

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

On the equity side, the only inclusion rule is to pass a minimum size threshold of one million euros. •

More details can be obtained from individual EDHEC publications describing the theoretical background and technical development of each component of this methodology.

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[10] Index constituents' weights are computed in a reference currency (here euros), irrespective of the choice of the reporting currency of the index.
[11] These rules permit extreme returns and volatility to be avoided due to very low book or total senior debt outstanding values as a project approaches its maturity.