# Benchmarking Long-Term Investment in Infrastructure

## Objectives, roadmap and recent progress

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# About the Author

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# Executive Summary

*Matching the huge demand for capital investment in infrastructure projects around the world with the available supply of long-term funds by institutional investors -- be they pension funds, insurers or sovereign wealth funds -- has never been so high on the international policy agenda. This policy momentum, illustrated by the recent focus on long-term investment in infrastructure by the G20, coincides with the steadily growing investment appetite from institutional investors for unlisted and illiquid assets.*

*However, solid evidence supporting the infrastructure investment narrative is still missing, and full-fledged investment solutions demonstrating the benefits of infrastructure investment for institutional investors remain elusive. Today, documenting the investment characteristics of long-term investment in infrastructure has become a pressing question.*

In this paper, we discuss the need and propose an approach to benchmark long-term investments in infrastructure, where long-term investment simply refers to any unlisted and illiquid asset.

We first highlight the reasons why benchmarking long-term infrastructure investments has become a *sine qua non* to match the supply and demand of long-term capital, improve asset allocation outcomes for investors and support the development of the economy.

We propose a roadmap detailing the steps to create benchmarks of long-term infrastructure investments. Drawing on recent research,[1] we also discuss how this roadmap can be implemented.

**The need to inform asset allocation decisions and to adapt regulation**

Asset allocations to long-term investments in infrastructure require a/ that investors know what risk and performance to expect over time and in different economic environments and b/ that regulators understand what risks investors are taking.

As a consequence, benchmarking the expected behaviour of long-term infrastructure investments is necessary to allow investors to fully integrate infrastructure investment into their asset-liability management exercises, as well as to calibrate the risk-based regulatory frameworks that make these investments possible (or not) in the first place. The information created with such benchmarks will be instrumental to match the supply and demand of long-term capital.

**Substantial investment in infrastructure by long-term investors cannot take place without adequate measures of expected performance and risk.** However, market mechanisms have so far failed to create the information necessary for the supply and demand of long-term investment to meet on a significant scale.

Today, asset allocation to **long-term infrastructure investments remains a puzzle.** Indeed, while they can a priori be expected to deliver improved diversification, better liability hedging and less volatile valuations than capital market instruments, investment solutions that can demonstrably give access to this 'investment narrative' have remained few and far between.

Quantitative analysis remains necessary to help answer investors' most basic and pressing question: is investing in illiquid infras-

1 In 2012, EDHEC-Risk Institute created a thematic research program on infrastructure investment and established a Research Chair dedicated to infrastructure debt investment with the support of NATIXIS. In 2013, a second Research Chair focusing on the characteristics of unlisted infrastructure equity was created with the support of Meridiam Infrastructure & Campbell Lutyens.

tructure assets really relevant as an asset allocation decision?

Likewise, regulators require empirical evidence before they can consider adapting the risk-weights that are currently applicable to long-term investment in infrastructure.[2]

### A double challenge: data collection and asset pricing

The nature of long-term investment in infrastructure makes the creation of investment benchmarks very challenging: **extensive data collection, while absolutely necessary, will not be sufficient to create the necessary benchmarks.**

First, limited cash flow data are available. They are scattered amongst numerous private investors and lenders, and little or no effort has been made to construct a database of these cash flows. Today, this database must be built, and this is one of the steps on our proposed roadmap.

Nevertheless, *even with such a database*, empirical observations about infrastructure equity and debt cash flows will remain truncated in time and limited in the cross-section. Infrastructure cash flow time series are incomplete: by definition, the immense majority of infrastructure projects currently investable are far from having reached the end of their lives. Hence, most of these cash flows remain in the future for which very little, if any, comparable investments currently exist.

Indeed, in the cross section, the type of infrastructure projects that have been financed over the past few decades has evolved and is not necessarily representative of investment opportunities today.

The second challenge is the (almost) complete absence of market valuation for projects that are invested at one point in time and are then held to maturity. While unlisted infrastructure project equity may be traded in secondary markets, this is rare and very few transactions exist. The same is even more true for infrastructure project debt.

In the majority of cases, the only observable price information is the initial equity investment and debt originated at the beginning of infrastructure investment projects, given a cash flow forecast or "base case". We may also observe updated cash flow forecasts spanning the remaining life of each investment. Finally, we can observe realised cash flows and cash flow ratios, but not the for the entire life of individual projects.

In other words, the challenge is to estimate the performance of an asset that is lumpy, held to maturity, for which most cash flows remain to be observed, with limited granularity in the cross-section, with (almost) no market prices.

The roadmap that we propose addresses the paucity of available data and aims to document the performance and risks of long-term investment in infrastructure in terms that are relevant to investors and regulators.

### The roadmap: eight steps towards long-term institutional investment in infrastructure

Our roadmap requires a two-level approach, starting with understanding financial assets, before documenting the behaviour of different portfolios built with such instruments.

2 The recent debate around Solvency-II and long-term investment led to an impasse for lack of sufficent empirical evidence.

At the financial asset level, five steps are necessary to clarify and document the performance of unlisted infrastructure equity and debt:

1. Define your terms: Today infrastructure investment is ill-defined. The first step of our roadmap is the to agree on unambiguous definitions of what financial instruments long-term investment in infrastructure refers to.

2. Design adequate valuation and risk measurement methodologies: With clear and consensual definitions of underlying instruments, adequate valuation and risk measurement methodologies can be developed that take into account the infrequent trading of most underlying infrastructure equity and debt. The proposed methodologies should also lead to the definition of the minimum data requirement (MDR), necessary to derive the required performance and and risk estimates.

3. Determine the data collection requirements: While ensuring theoretical robustness is paramount to the reliability of performance measurement, a trade-off exists with the requirement to collect real world data from market participants, in order to keep this process realistic and affordable.

The determination of a parsimonious dataset for asset pricing will also inform the standardisation of a new investment data collection and reporting framework.

4. Standardise performance reporting: The standardisation of infrastructure investment data collection will allow the emergence of an industry-wide reporting standard. This reporting standard can increase transparency between investors and managers, maximise industry participation and reduce the cost of compliance.

5. Create a database of infrastructure equity and debt cash flows: With the identification of the required data and a standardised reporting/data collection template, a database of infrastructure project cash flows can be built to apply the methodologies mentioned above, and it can be managed by an independent organisation to address potential conflict of interests.

At the portfolio level, three more steps are necessary to arrive at useful long-term investment benchmarks in infrastructure:

6. Identify building blocks: A number of risk factors can be expected to systematically explain investment performance in infrastructure projects. Once the most homogenous sub-groups of individual infrastructure finance equity and debt instruments have been identified (e.g. greenfield vs. brownfield), relevant investment strategies using these building blocks can de designed.

The statistical validation of these insights is a key step on the roadmap towards infrastructure investment benchmarks, and will ensure that individual building blocks exhibit low levels of correlation between themselves.

7. Define relevant investment strategies: As long-term illiquid assets, a basket of infrastructure projects is not easily or instantly investable. However, the building blocks discussed above can be used independently or combined to guide different investment strategies with regard to long-term infrastructure and that can help achieve investors' long-term objectives.

8. Investment benchmarks: These strategies can be used as benchmarks to assist in investment decision making, performance and risk measurement. Using historical

data, the correlation of each strategy's performance with other asset classes (e.g. corporate debt, public or private equity etc.) can be measured and, with continued data collection it can be estimated with increased accuracy.

### The role of infrastructure project finance

To achieve the first objective on the roadmap (to define the underlying assets), we argue that the financial instruments considered adequate should meet three criteria:

- There should be a good reason to believe that such financial assets have a different investment profile than existing partitions of the investment set i.e. corporate bonds, private equity, etc.

- They should exist in large enough quantities to be relevant at the strategic asset allocation level for a typical investor.

- Investors should be able to construct portfolios of sufficient granularity to achieve a sufficient degree of diversification and to converge towards an average effect (the benchmark).

Today, project finance debt and equity are the main types of financial assets that meet all three criteria and can serve as the reference instruments for the construction of infrastructure investment benchmarks. Indeed:

- The largest pool of investable, standalone infrastructure projects was created using project finance (USD3.3 trillion of financing closed over the past 15 years).

- Project finance benefits from an internationally recognised and uncontroversial definition in the Basel-II Capital Accord.

- Because of its specific corporate governance, it can be expected to have a unique risk/return profile and thus to contribute positively to long-term investors' portfolio choices.

### Valuation and risk measures

The second step of the roadmap requires the creation of asset pricing methodologies that can address one of the fundamental difficulties of investing in highly illiquid assets: the absence of a large number of trades or of publicly available cash flow data.

In the last part of this position paper, we present some of the results of two forthcoming papers addressing, respectively, the valuation of infrastructure project finance equity and debt.

We highlight the fact that even if all existing empirical data were aggregated, valuing long-term infrastructure debt and equity would still have to rely on cash flow models because a significant part of relevant and comparable cash flows still lie in the future. We suggest the use of Bayesian inference to build cash flow models that can be updated as new information becomes available.

The documentation of infrastructure cash flow dynamics requires a quasi-forensic effort to identify generic project financing structures and calibrate the relevant cash flow models. Once cash flow dynamics are understood, to the best of our current empirical knowledge, valuation and performance measurement can take place.

Our proposed approach takes advantage of the fact that project finance is well-documented at the time of investment, which makes it possible to group infrastructure investments into categories that are expected to correspond to homogenous cash flow processes.

In two forthcoming papers (Blanc-Brude and Ismail 2014; Blanc-Brude, Hasan, and Ismail 2014), we argue that by partitioning the investable universe of infrastructure projects with tractable cash flow models characterised by well-documented parameters – such as initial leverage, amortisation profile, and typical average debt service cover ratio throughout the project lifecycle – we can apply Bayesian techniques and elicit the prior distribution of a stochastic cash flow process that can subsequently be updated with empirical observations as they become available.

Thus, using a minimal amount of input data i.e. observing initial investment values, base case and revised equity cash flow forecasts even for a limited number of projects (per generic type), as well as actual dividend payouts even with truncated time series, we can derive full time series of discount rates.

Likewise the performance of infrastructure project finance debt should be properly modelled and measured by taking into account the endogenous nature of credit risk in project finance, that is, the active role played by lenders across the lives of these instruments to maximise recovery rates and indeed returns per unit of risk taken.

Using these approaches to infrastructure equity and debt valuation, we can compute asset values, period rates of return, yield to maturity and a series of risk measures including expected loss, effective duration, value-at-risk, conditional value-at-risk for individual instruments and portfolios of equity and debt in infrastructure projects.

These results remain conditional on information available today, and on the initial segmentation of the unlisted infrastructure project equity universe into generic project types, each of which represents a single underlying cash flow process.

Still, we show that it is possible to build performance measures that can inform portfolio construction and, eventually, asset allocation, for highly illiquid and seldom traded instruments.

We also find that model calibration using even limited datasets leads to substantial variance reduction of the parameter estimates.

In other words, the learning potential from a database of project cash flows combined with Bayesian methods is rapid and significant even with initially small samples. Hence, more precise risk and performance measures are already achievable.

Crucially, this approach is completely transparent. This methodology is not a black box. It uses well-documented assumptions about generic infrastructure project structures that can be refined to reflect an industry consensus. Furthermore, Bayesian models mostly involve simple algebra and calculus.

### Next steps

Thus, despite the absence of large or even complete datasets, the benchmarking of long-term investment in infrastructure can be achieved in a manner that is both useful and relevant to asset allocation decisions and the calibration of prudential regulatory frameworks. Our use of the prism of project finance to model and measure the volatility of underlying cash flows is instrumental in this respect.

Since project finance corresponds to a well defined category of financial instruments with unique characteristics, as well as the largest and most representative pool of infrastructure financing instruments, project finance debt and equity are well suited to be reference instruments for the construction of long-term infrastructure investment benchmarks.

EDHEC-Risk Institute's effort to implement this roadmap continues with the standardisation of data collection and reporting of infrastructure investment cash flow data and performance, and the development of the first global database of project finance equity and debt cash flows.

Implementing our proposed roadmap will make it possible to create and produce long-term infrastructure investment benchmarks, and to calibrate the relevant prudential regulatory frameworks.

# Section 1: Introduction

*Matching the huge demand for capital in infrastructure projects around the world with the available supply of long-term funds by institutional investors, be they pension funds, insurers or sovereign wealth funds, has never been so high on the international policy agenda. This policy momentum, illustrated by the recent focus on long-term investment in infrastructure by the G20, coincides with the steadily growing investment appetite from the same investors for unlisted and illiquid assets. However, full-fledged investment solutions demonstrating the benefits of long infrastructure investment for institutional investors remain elusive. Documenting the characteristics of long-term investment in infrastructure has become a pressing question.*

In this paper, we discuss the need to benchmark long-term investments in infrastructure, where long-term investment refers to any unlisted and illiquid asset. Indeed, while investment solutions may be created that offer investors greater liquidity, at the underlying level, most investable infrastructure remain unlisted and highly illiquid.

We argue that asset allocations to long-term investments in infrastructure require a/ that investors know what risk and performance to expect over time and in different economic environments and b/ that regulators understand what risks investors are taking.

As a consequence, benchmarking the expected behaviour of long-term infrastructure investments is necessary to allow investors to fully integrate long-term infrastructure investment into their asset-liability management exercises, as well as to calibrate the risk-based regulatory frameworks that make these investments possible (or not) in the first place. The information created with such benchmarks will be instrumental to match the supply and demand of long-term capital.

The need for benchmarks of long-term investment in infrastructure may seem incongruous at first. After all, infrastructure projects are lumpy and highly idiosyncratic endeavours. If every project is different, what can we learn from a benchmark?

However, in modern finance, asset allocation is not about picking individual investments, but instead focuses on investing in groups of reasonably homogenous assets giving access to remunerated risk factors. The performance of each of these groups can be evidenced by a benchmark.

Long-term investment in infrastructure assets is related to a broader trend amongst institutional investors to improve portfolio diversification or seek higher returns through alternative investments, to invest increasingly outside of public capital markets, to find sufficiently long-dated instruments with a more attractive performance than government bonds, and to invest in inflation-linked securities other than low-yielding Treasury Inflation Protected Securities (TIPS). One of the salient feature of these emerging investment choices is the decision to buy assets that are infrequently traded and to hold them until maturity.

In the absence of investment benchmarks, the growing interest of investors for infrastructure investment has been motivated by what we call the "infrastructure investment narrative" (see Blanc-Brude 2013), that is, the notion that infrastructure projects uniquely combine the following characteristics:

- Low price-elasticity of demand for service, hence low correlation with the business cycle
- Monopoly power, hence pricing power, hence an inflation hedge
- Predictable and substantial free cash flow
- Attractive risk-adjusted cash flows,

available over long periods

• Access to unlisted, illiquid financial assets

That is, investing in infrastructure *implies*:

• Improved diversification

• Better liability-hedging, including inflation protection

• Less volatility than capital market instruments

Of course, this narrative is also a model i.e. it describes the expected characteristics of the average infrastructure project. Individual projects in specific jurisdictions, relying on one or other form of contractual or regulatory arrangement, may only have some or none of the above characteristics.

Hence, this narrative is a form of "benchmark", albeit one that does not rely on any empirical observations, but on which investors currently considering investing in infrastructure must nevertheless rely to form their expectations and make allocation decisions.

Today, a quantitative analysis of the above narrative is necessary to help answer investors' most basic and pressing question: is investing in illiquid infrastructure assets really relevant as an asset allocation decision?

In the rest of this paper, we discuss a way forward to answer this question, highlight recent advances in the area of valuation and risk measurement for unlisted infrastructure and debt investments, as well as ongoing data collection efforts.

In the next section, we first discuss why creating long-term investment benchmarks in infrastructure would help address two important sets of issues: first, the need for measures of expected performance and risk for the purpose of asset allocation and prudential regulation, and, second, the inability of the market to create this information, and the role of independent research to help address this market failure.

Section 3, proposes a roadmap highlighting the necessary steps towards adequate and proper benchmarking of long-term investments in infrastructure equity and debt. At the underlying level, it involves the definition of relevant financial instruments, adequate valuation and risk measurement methods and the identification of a realistic and efficient data collection template. At the portfolio level, it requires identifying homogenous "building blocks" of infrastructure debt or equity, designing strategies using these blocks (portfolio construction) and comparing their performance with other assets.

Following the first step on our roadmap, section 4 proposes a clear and uncontroversial, albeit restrictive, definition of the financial instruments found in infrastructure projects and based on the Basel-II definition of infrastructure project financing.

Next, section 5, discusses the current state of empirical knowledge about infrastructure project cash flows as well as the approach taken in two forthcoming papers to measure value, returns and risks in, respectively, infrastructure project equity and debt.

Section 6 concludes and highlights ongoing and future work by EDHEC-Risk Institute towards the creation of benchmarks for long-term investors in infrastructure.

## 2 Why benchmark unlisted infrastructure investments?

### 2.1 Informing asset allocation decisions

Long-term investors need benchmarks to make strategic asset allocation decisions which, as is well documented in the academic literature, explain most of the outcome of the investment process. Investing in illiquid infrastructure assets is a long-term allocation decision and thus requires having a view of expected performance[3] over time and economic conditions. This view necessarily is a statistical construct of the distribution of possible outcomes at different horizons i.e. a benchmark.

Thus, a key question is to know if the expected performance a given basket of infrastructure project debt or equity can add value to an investor's existing asset allocation, including on the liability management side, and what are the factors that systematically explain this performance. A related question is to know how large such a basket has to be to yield this average or expected performance given that individual assets can be lumpy, and that achieving substantial diversification of idiosyncratic risks may require very large portfolios.

Long-term investors also need long-term infrastructure investment benchmarks to choose and monitor the performance of specialist asset managers, or of their own direct investment program. Without the constant feedback of market prices, long-term investment increases information asymmetry between investors and their managers, as well as investors' corollary demand for monitoring and reporting. The relative added-value of unlisted infrastructure investments to asset allocation policies cannot be adequately monitored without a performance measurement tool i.e. a benchmark.

Finally, long-term infrastructure investments can potentially play different roles in performance-seeking or liability-hedging portfolios, and investors need long-term investment benchmarks to identify the most relevant strategies using infrastructure debt or equity as underlying instruments, given their own asset and liability management objectives and constraints.

### 2.2 Adapting prudential regulation

However, the opportunity for long-term investors to allocate funds to infrastructure is also conditioned by the adequacy of the prudential regulation framework which determines their ultimate costs of investment. Designing an adequate risk-based prudential framework requires accurate risk measures which do not distort investment decisions beyond the objective of creating the necessary risk buffers.

For example, the Solvency-II framework approaches the calculation of solvency capital requirements using building blocks representing a set of risk modules and submodules, the linear combination of which is known as the Standard Formula. By focusing on broad categories of risk factors, the Standard Formula implicitly addresses the strategic asset allocation of a typical insurer.[4]

Thus, revising the Solvency-2 Standard Formula to accommodate long-term investment in infrastructure, as was recently discussed,[5] first requires the demonstration that such investments are relevant as a matter of strategic asset allocation for insurers.[6]

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3 We use the term "performance" to refer to risk-adjusted returns.

4 If they feel that the proposed risk modules and their calibration do not represent their individual situation, insurers have the choice of proposing their own risk model. The Standard Formula is thus meant to embody the average case.

5 See Blanc-Brude and Ismail (2013a) for our contribution to this debate.

6 This point is implicit in other parts of the Solvency-2 framework. For example, calibrating the "Global Equities" submodule based on the MSCI World Developed Price Equity Index assumes that, in terms of equity risk, a typical insurer is exposed to a market-cap weighted measure like the MSCI World. The use of the Standard Formula implies that such benchmarks are a sufficient approximation of the risk taken by a typical insurer.

Without benchmarks however, the risks inherent in long-term investment are not properly documented and their prudential treatment defaults to the most conservative stance.

Inadequate performance measurement leads to a regulatory dead-end: faced with unknown quantities, prudential regulation penalises long-term unlisted bets, effectively making long-term investment in infrastructure prohibitively expensive.

Instead, creating and calibrating adequate risk measures for typical or ad hoc exposures to long-term infrastructure investments would permit adapting existing prudential frameworks and internal models to avoid distorting asset allocation policies to long-term investments beyond what actual risk levels require.

Such improvements of the prudential regulatory framework are relevant to most market participants, including:

*Lenders:*

1. Regulated banks: Infrastructure debt benchmarks will allow better design and calibration of the risk weights for individual and portfolios of infrastructure project finance loans in the context of the current implementation of Basel-III.

2. Shadow banks: Infrastructure debt credit risk benchmarks may also be used to regulate investment funds or other non-bank entities originating infrastructure debt. The debate about the regulation of closed-ended debt funds typically revolves around imposing fund leverage and diversification constraints.

Thus, the relevant benchmarks can be can be used to asses the risks of long-term debt funds investing in infrastructure debt.

*Long-term investors:*

1. Insurers: Benchmarking is necessary to calibrate the impact of infrastructure credit spread and equity shocks, or, alternatively, to design a dedicated "infrastructure project finance" risk module. Building on the current debate about Solvency-II and its treatment of long-term investments, adequate risk-modules may be designed and calibrated. Beyond the so-called standard formula, internal models require similar risk measures and would benefit from a dedicated infrastructure benchmark.

2. Pension funds: Likewise, pension funds that are required to fulfil risk-based capital requirements will benefit from improved measures of the risks found in long-term infrastructure investments.

*Solution providers:*

1. Alternative asset managers: Infrastructure debt and equity benchmarks also allow the calibration of risk-based capital requirements for fund management companies (FMCs). Adequate methodologies for infrastructure asset valuation and risk measurement, standardisation of data collection and performance reporting, will also better define business conduct requirements for FMCs involved in infrastructure investing.

2. Collective investment schemes (CIS): CISs offering access to infrastructure-related products would benefit from dedicated valuation methodologies and standardised data reporting framework designed for the purpose of benchmarking the performance of infrastructure investments. CIS also frequently have risk limits, thus better benchmarking can help them measure manage risk exposures; and in jurisdictions where CIS operators are required to hold risk-base capital, calibration needs also exist.

With the creation of benchmarks of long-term infrastructure equity and debt investment, better measures of performance, risk and duration can be available, as well as the calculation of the most adequate risk-weights. This would significantly improve origination conditions, investment solution design, prudential regulation and asset allocation decisions.

### 2.3 Correcting a market failure

While achieving substantial investment in infrastructure by long-term investors is thus difficult to imagine without the creation of adequate measures of expected performance and risk, market mechanisms have so far failed to create the information necessary for the supply and demand of long-term investment to meet. Today, asset allocation to long-term infrastructure investments remains a puzzle.

For instance, capturing the performance of infrastructure equity has not proven straightforward for investors. So far, exposure to infrastructure equity has been mostly limited to two routes: the so-called listed infrastructure and unlisted private equity funds or "infrastructure funds", the immense majority of which are clones of private equity (PE) funds with similar investment timeframes, fee structures and use of fund-level leverage.

As we argue in Blanc-Brude (2013) following a comprehensive review of existing research on the subject, as well as our own research using updated datasets, neither listed or unlisted infrastructure equity products have delivered the suggested "investment narrative" that we discussed in our introduction.

Listed infrastructure indices amount to cap-weighted baskets of stocks selected mostly on the basis of their industrial categorisation (utilities, airpots, energy, etc.) Because utilities tend to be very large, such "strategies" lead to over-concentration as measured by the effective number of stocks.[7]

And while infrastructure PE funds can be distinguished from other PE funds by their larger size and the slightly longer period during which these "infrastructure funds" hold their assets, it is at best a diversifier of the PE space, but not something fundamentally different. It is neither about getting exposure to long-term stable cash flows, or an inflation hedge, but only, in the best cases, a profitable exit in the medium term. Table 1 summarises the findings of the existing literature.

The disconnect between the investment narrative – a series of intuitions drawn from economics – and the observed performance of available investment products, springs from a lack of clarity about what is meant by "infrastructure" in the first place.

The definition of the underlying often remains vague and is driven by considerations about "real" assets and a number of assumptions about the characteristics of firms in certain sectors. Hence, the infrastructure sector is often described using a series of industrial classifications such as utilities, transport, energy, water, public buildings &tc.

Perhaps unsurprisingly, without a clear definition of what infrastructure is understood to be from a financial perspective, no clear picture emerges from the evidence on the per-

Table 1: Recent research findings on the performance of "infrastructure" equity

| Expected behaviour | Listed infastructure indices | Unlisted infrastructure PE funds |
|---|---|---|
| Low risk | No | No |
| Low correlation with the business cycle | No | No |
| Long-term | No | Exits after 5 to 7 years |
| Excess returns | No | Yes, with fund level leverage |
| Limited drawdown | No | No (impact of the credit cycle) |
| Inflation protection | No | No |

*Source: Newell and Peng (2007, 2008); Sawant (2010); Rothballer and Kaserer (2012); Bitsch et al. (2010); Weber and Alfen (2010); Bird et al. (2012); Blanc-Brude (2013)*

7 The effective number of constituents of portfolio of N constituents is the inverse of the Herfindahl-Hirschman Index, which measures the concentration of the portfolio on a scale from 1/N to 1. When a portfolio is equally allocated to its N constituents, its effective number of constituents is equal to N, its nominal number of constituents. As concentration rises, the effective number of constituents tends towards unity (see Amenc, Goltz, and Lodh 2012).

formance of existing infrastructure-related products. These strategies are not driven by well-identified mechanisms at the underlying level, which could be expected to correspond to remunerated risk factors. They are simply ad hoc asset selection schemes in the listed and unlisted spaces.

The significant lack of knowledge about the expected behaviour of infrastructure debt and equity and the various portfolios that can be built using them makes understanding infrastructure investment from a strategic asset allocation standpoint virtually impossible.

Documenting expected returns, risk measures and correlations (i.e. the necessary ingredients to take a view on long-term investing in infrastructure) can only be achieved with a clear and well-accepted definition of underlying instruments, and a transparent proposal about the investment strategy, including its diversification and leverage.

This lack of knowledge about the performance of infrastructure assets is, of course, not new, but as long as the decision to invest in long-term unlisted assets was at best a subplot of the (relatively small) alternative investment allocations made by large institutional investors, this was unproblematic.

However, as soon as investors consider making substantial allocations to infrastructure investment, ranging from several percentage points to almost a fifth of their assets in some cases, the absence of better knowledge about long-term unlisted investments such as infrastructure becomes a significant impediment to new investments.

This partly explains why investors have remained mostly unable to make greater forays into the infrastructure sector.[8]

In the future, meeting investors' and regulators' need for better information of the performance of infrastructure assets and investment strategies will determine the extent to which long-term investment in infrastructure can take place.

Unfortunately, today this information remains unavailable. Beyond the question of defining infrastructure investment discussed above, typical reporting by infrastructure PE funds does not improve the quality or relevance of the information available to investors: existing research on PE performance overwhelmingly concludes that the self-reported net asset values (NAV), internal rates of return (IRR) and investment multiples reported by PE managers are both inaccurate and inadequate.

Inaccuracy springs from the tendency of PE managers to report their performance opportunistically. For example, Jenkinson, Sousa, and Stucke (2013) look at the quarterly valuation history of 761 PE funds invested by CalPERS and find that PE managers tend to report conservative valuations hence smoothing returns, except when they are audited (fourth quarter "Santa effect") and when they are raising a follow-on fund, in which case reported valuations soar for a few quarters before returning to their pre-fund raising levels.

Other papers arrive at similar conclusions. The inadequacy of reported performance is a function of the choice of performance measures. In their comprehensive critique of the performance monitoring of typical private equity funds, Phalippou and Gottschalg (2009) show that pooling individual IRRs creates misleading results because IRRs cannot be averaged.

The authors also find a large negative correlation between duration and performance in private equity funds, which, combined with the incentive to time cash flows strategically, tends to create an upward bias in reported performance as well as incentives to exit investments quickly.

Likewise, Jenkinson, Sousa, and Stucke (2013) find that current reported IRRs are poor predictors of the ultimate returns of PE funds.

In a nutshell, current reporting in the long-term investment space is grossly inadequate

8 e.g. Australia may be a pioneering market for infrastructure investment but Australian super funds only invest 3% of their assets in infrastructure.

for the purpose of asset allocation. With unsatisfactory performance measurement and monitoring by PE managers, a number of large institutional investors have ceased to delegate their investments in unlisted firms and have instead internalised the functions of acquiring and managing infrequently traded assets such as infrastructure.[9]

This trend towards direct investment in illiquid assets is most developed amongst Canadian pension funds, a few large European pension funds and sovereign wealth funds.

Because long-term investment in unlisted firms leads to a significant increase in the demand for performance monitoring, and because the PE industry has been unable to provide better information to investors, in particular the kind of performance measure that would be meaningful from an asset allocation perspective, the largest investors have resorted to internalise the investment, monitoring and reporting necessary to access and benefit from long-term unlisted investments.

Whether or not there can be value in delegation to a specialist manager is beyond the scope of this discussion. Importantly, the so-called Canadian model neither solves the question of how to benchmark an allocation to long-term infrastructure investment ex ante, nor that of the ongoing monitoring of investment performance.

Instead, investors are left to discover what DIY infrastructure investing can deliver ex post without much guidance about portfolio construction and assessing diversification benefits.

Faced with a retreat from such large accounts as the Canadian pension industry, why are infrastructure PE managers not offering to improve their monitoring and reporting so that investors can benefit from delegation while making better-informed asset allocation choices? In effect, some managers are already evolving towards new PE models allowing investors to gain the kind of longer-term exposure they require and to understand expected performance better.

Moreover, the tendency for institutional investors to create large or very large unlisted infrastructure allocations is a recent development and the need to monitor and benchmark performance has only recently become more pressing.

But the failure of the PE industry to provide satisfactory monitoring and reporting to long-term investors is also **a collective action problem**: most of the necessary information is private and scattered amongst numerous firms. Data collection, when it exists, is ad hoc and relies on existing practices instead of promoting data collection according to the requirements of proper asset pricing and risk measurement methods.

While PE managers could be more transparent and aim to provide performance measures that are more relevant to long-term investors, taken individually, none of them has access to enough information to answer the PE asset allocation question.

On the debt side, the same dichotomy exists between relatively more liquid instruments (bonds) and genuinely long-term portfolios of illiquid (private) debt, mostly loans extended to infrastructure projects. In the project bond space, as for equities, the relevance of an asset selection scheme based on industrial classifications may be questionable.

More generally, institutional investors have been exposed to corporate bonds issued by utilities and other network operators for decades and such instruments are thus unlikely to contribute anything new to their existing asset allocation choices.

Instead, most infrastructure project debt is created as private bank loans, but so far, any evidence of the characteristics of a portfolio of long-term loans extended to infrastructure projects has remained very scarce.

9 Using fund IRRs also reveals a well-documented identification problem i.e. the same cash flows may be returned to investors while individual assets have opposite betas and if alpha is allowed to be positive, the identification problem only grows. In effect, direct IRRs comparisons requires making assumptions about the functional form of fund return distributions and on such assumptions being constant across time and between funds (Korteweg and Sorensen 2007).

Exiting studies of credit risk in infrastructure project finance (see for example Moody's 2013) limit themselves to the risk profile of individual loans but have not delved into issues of valuation, duration, correlations, or portfolio construction.

Indeed, few infrastructure debt investment solutions existed until very recently. In this space, a lot can be learned from the difficulties experienced by investors over the past decade with accessing unlisted infrastructure private equity funds.

### 2.4 Creating a public good

These issues characterise all long-term investments, beyond unlisted infrastructure equity or debt. Managers and (direct) investors do not have enough information to benchmark their own investment choices and there is no publicly available information through market prices to validate or correct their investment decisions.

Hence, there is a clear role to play for policy makers and academia to address a collective action problem and support the standardisation of data collection and the creation of adequate investment benchmarks for the purposes of long-term investing in unlisted assets such as infrastructure.

Without such new knowledge, it will remain considerably difficult for long-term investors to make long-term allocations to infrastructure debt and equity, or for regulators to make it possible for them to do so in a significant scale.

Indeed, the same need to create new knowledge on the risks of long-term investment is also patent on the regulatory side: it is widely acknowledged that the current prudential regulatory framework is ill-suited to long-term investment (see for example Faull 2012), especially in the case of infrastructure (MAS 2013).

As we argued above, designing proper benchmarks to measure the risks of well-documented investment strategies using well-defined underlying instruments can considerably improve the accurate calculation of the relevant risk weights.

More accurate risk measures almost certainly imply lower capital charges, and the more effective and efficient intermediation of long term capital.

Finally, benchmarking long-term infrastructure investment should be instrumental to improve public infrastructure procurement as well. A better understanding of the risks and expected financial performance of long-term public-private contracts shoudl both optimise the value-for-money such contracts from the point of view of the tax payer and help minimise poltiical risk for investors by increasing transparency.

Next, we highlight a roadmap towards the creation of adequate, transparent and rigorous investment benchmarks providing investors and regulators with an impartial view of expected performance for well-defined strategies using infrastructure debt and equity as underlying instruments.

### 3 A roadmap to develop long-term infrastructure investment benchmarks

Benchmarking long-term investments in infrastructure requires a two-level approach, starting with underlying instruments, before documenting the behaviour of different portfolios built with such instruments.

#### 3.1 Documenting underlying instruments

At the underlying level, five steps are necessary to clarify and document the performance of infrastructure financing instruments, be they on the equity or debt side:

1. Definite your terms: Improving the benchmarking and regulation of any type of investment first requires well-defined underlying assets. Today infrastructure investment is ill-defined and the first step of our roadmap is the creation of unambiguous definitions of what financial instruments long-term investment in infrastructure refers to.

Indeed, infrastructure assets are not real assets but financial contracts (see Blanc-Brude 2013 for a detailed discussion of the contractual nature of infrastructure assets) and from an asset allocation perspective, industrial classifications such as "roads" or "power" are close to useless.

A first solution to the absence of a widely agreed definition of "infrastructure", which we develop in section 3, is to focus on Project Finance debt and equity as defined in Basel-II. Other approaches to infrastructure investment at the underlying level must also be developed, as long as they refer to well identified financial instruments (e.g. the equity capital of certain types of regulated network operators).

2. Design adequate valuation and risk measurement methodologies: With a clear and broadly accepted definition of underlying instruments, adequate valuation and risk measurement methodologies can be developed that take into account the infrequent trading of most underlying infrastructure equity and debt.

By "adequate" we mean that such methodologies should rely on the rigorous use of asset pricing theory and statistical techniques to derive the necessary input data, while aiming for parsimony and realism in terms of data collection. The proposed methodologies should lead to the definition of the minimum data requirement (MDR), necessary to derive robust return and risk estimates.

3. Determine the data collection requirements: While ensuring theoretical robustness is paramount to the reliability of performance measurement, a trade-off exists with the requirement to collect real world data from market participants. In particular, proposed methodologies should aim to minimise the number of inputs in order to limit the number of parameter estimation errors.

Adequate models should also focus on using data points that are known to exist and are already collected/monitored or could reasonably easily be collected. In all cases, data requirements should be derived from the theoretical framework, not the other way around.

In fact, the amount of available data will be initially limited in scope, since not all types of infrastructure projects exist in large numbers, and in time, because infrastructure investments may have multi-decade lives and available records are unlikely to span such periods. Such data paucity can also be addressed especially if models are designed to allow for learning. We return to these issues in section 4.

Whether the necessary data already exists or not, the determination of a parsimonious dataset for asset pricing will also inform the standardisation of a new investment data collection and reporting framework.

4. Standardise performance reporting: The standardisation of infrastructure investment

10 We detail this point in section 4.

11 While the operating phase of infrastructure projects is not risk-free, on average infrastructure projects are characterised by a sequential resolution of uncertainty, in particular constant de-leveraging, which justifies the premise of a dynamic, downward trending risk profile.

data collection allows the emergence of an industry-wide reporting standard, which can be recognised by investors and regulators alike as "best practice".

This reporting standard will increase transparency between investors and managers, who can then be mandated to invest in a well-defined type of instrument and commit to report the relevant data.

Adequate reporting will also maximise industry participation and reduce the cost of compliance.

5. Create a database of infrastructure equity and debt cash flows: With the identification of the required data and a standardised reporting/data collection template, a database of infrastructure project cash flows can be built to apply the methodologies mentioned above.

Initially, historical data can allow documenting the past performance of well defined infrastructure debt and equity instruments. Next, the ongoing collection of project cash flows can permit the production of regular updates of the known performance of such instruments over time.

Next, once the adequate valuation and risk measurement methodologies have been determined for a given type of financial instrument, and data collection and reporting has been standardised, the benchmarking of long-term infrastructure investments can effectively take place.

What performance should a long-term infrastructure investment benchmark aim to capture?

While a portfolio consisting of a representative basket of assets is the most intuitive benchmark, it is also virtually impossible to invest in the case of unlisted infrastructure debt and equity i.e. given currently available infrastructure investment vehicles, an investor cannot instantaneously buy a basket of assets that is representative of investable infrastructure projects in existence at that point in time.

It may be possible to invest in such a representative basket over time, but this may take several years, by which time what constitutes a representative basket of infrastructure investments is likely to have changed with the evolution of public procurement policies.

Instead, the most useful long-term investment benchmarks are likely to be a combination of well-documented "building blocks" capturing the most homogenous sub-groups of individual infrastructure finance equity and debt instruments. These building blocks can be used independently or combined to guide different investment strategies

### 3.2 Building relevant portfolios

Thus, at the portfolio level, three more steps are necessary to arrive at useful long-term investment benchmarks in infrastructure:

6. Identify building blocks: A number of risk factors can be expected to systematically explain investment performance in infrastructure projects. For example, Blanc-Brude (2013) shows that the most important such factors are the contractual features of individual investment projects, in particular to what extent they are exposed to commercial risks, as well as the development of the typical project lifecycle, which, in infrastructure project finance, tends to correspond to the continuous de-leveraging of the firm's balance sheet.

Thus, the risk/return profiles of most infrastructure project financing instruments can, for example, be grouped by revenue risk profile on the one hand, and lifecycle stage on the other.

In other words, at a given point in time, infrastructure debt or equity can correspond to what is typically known as greenfield or newly built assets and brownfield or already existing and operating ones. The former are typically riskier and yield higher returns, the later less so.

The same debt and equity instruments can also correspond to, say, toll roads and merchant power projects in the higher commercial risk, higher return category, and projects (also roads) that receive an income from the government based on the availability of service, or that have a take-or-pay off-take contract (possibly a power plant) by which their future income is independent of market conditions.

Such projects exhibit less volatile cash flows and lower returns than those exposed to commercial risks. Thus, any equity or debt instrument used to finance an infrastructure projects can be categorised according to such a two-dimensional matrix of revenue risk profile and lifecycle stage.

While these are not the only relevant systematic risk factors found in infrastructure projects, Blanc-Brude and Strange (2007) and Blanc-Brude and Ismail (2013b) show for example that such risk categories explain most of the variance of the level of credit spreads in project finance loans in Europe.

Once the most homogenous sub-groups of individual infrastructure finance equity and debt instruments have been identified, relevant investment strategies using these building blocks can de designed.

The statistical validation of these insights is a key step of the roadmap towards infrastructure investment benchmark, including ensuring that individual building blocks exhibit low levels of correlation between themselves.

7. Define relevant investment strategies: As long-term illiquid assets, a basket of infrastructure projects is not easily or instantly investable. However, the building blocks discussed above can be combined to embody different investment strategies with regard to long-term infrastructure and best achieve investors' long-term objectives.

For example, Blanc-Brude and Ismail (2013b) show that combining a block of greenfield debt with one of brownfield debt can create substantial diversification benefits i.e. increase returns and lower portfolio risk.

Thus, along the greenfield/brownfield spectrum there is a continuum of efficient portfolios that can serve as point of reference to build portfolio of infrastructure project debt using available instruments over a given period of time.

For each strategy, and using the asset pricing and risk measurement methodologies discussed above, various measures of return (period return, yield to maturity, return in excess of the investment base case), risk measures (expected loss, value at risk and expected shortfall) and (effective) duration can be computed and inform both the asset allocation process and the calibration of prudential regulatory frameworks or internal risk models, as discussed above.

8. Investment benchmarks: The strategies identified above can be used as long-term infrastructure investment benchmarks. Using historical data, the correlation of each strategy's performance with other investment opportunities (e.g. corporate debt, public or private equity etc.) can be measured and estimated on an ongoing basis.

This last step answers the all important question of the diversification potential of individual strategies using infrastructure instruments as underlying assets.

Implementing this roadmap requires an extensive data collection and modelling effort. Initially, historical data needs to be collected to calibrate valuation and risk models and provide a comparison with other types of assets.

Such benchmarks can also be computed on an ongoing basis to continuously inform investors' asset allocation choices but also provide them with performance assessment tools vis-à-vis infrastructure managers or their own direct investment program.

The adoption of standardised performance reporting by market participants will be instrumental in this regard.

In the next section, we return to the first point in the roadmap and propose a clear and uncontroversial definition of long-term underlying infrastructure instruments, on both the debt and equity sides.

## 4 Defining long-term investment in infrastructure

The Organisation for Economic Cooperation and Development (OECD) has put forward a definition of tangible infrastructure, which reads like a list of industrial sectors and sub-sectors: power plants, roads, water treatment, &c (OECD 2002). However, from an investment and regulatory perspective, a clear definition of what is meant by "infrastructure" remains elusive. All involved rely on the proverbial wisdom that they shall know it when they see it.

Instead, it is often argued that there is no universally accepted definition of infrastructure. For a long time, the energy sector (coal and gas-fired power plants, wind power, etc.) was considered to be separate from infrastructure, understood as network utilities (water, road and gas networks).

Today, with the growing popularity of infrastructure as an investment topic, more industrial sectors are covered by the umbrella term of infrastructure. In our view, the definition of what constitutes physical infrastructure is unimportant. The sectoral terminology is close to meaningless from an investment point of view, since it does not refer to a specific type of financial instrument or investible asset, and does not inform us about the contractual or regulatory characteristics of individual projects either.

We have argued above, that most existing investment products labeled "infrastructure", be they listed or unlisted, are at least one step removed from tangible infrastructure projects, and often have investment characteristics that makes them hard to distinguish from other existing investment categories, such as private equity as in the case of unlisted "infrastructure funds" or "low beta, large cap" as for listed utilities (see Blanc-Brude 2013).

To agree on a definition, we must return to our initial question: what is relevant for investors and regulators from the point of view of strategic asset allocation?

It can be unclear how investing in a limited number of industrial sectors (see the OECD definition for a full list) via vehicles that may be listed or not, have variable investment horizons, and are more or less leveraged, necessarily creates a unique or even a new investment opportunity for a large and well-diversified investor.

As argued above, a benchmarking methodology must rest on a clear definition of instruments used to build the reference portfolio. In Blanc-Brude and Ismail (see 2013c; Blanc-Brude and Ismail 2013d), we propose a definition of long-term investment in infrastructure, which is both universally recognised, captures the bulk of past and future underlying investments, and is relevant from an asset allocation perspective because it refers to a financial asset: non-recourse project financing.

### 4.1 Project finance as the reference long-term infrastructure investment

Today, non-recourse infrastructure project finance corresponds to the most relevant form of long-term infrastructure debt or equity for three reasons:

- It is the most significant form of investable, stand-alone infrastructure project by size;
- It benefits from an internationally recognised and uncontroversial definition;
- It can be expected to have a unique risk/return profile and thus to contribute positively to long-term investors' portfolio choices. We return to each point in turn below.

#### *4.1.1 Most investable infrastructure is project financed*

Project financing represents the bulk of investable, stand-alone infrastructure projects today, and in all likelihood, the majority of new infrastructure projects to be financed in the future.

We estimate that more than USD3Tr of project financing was closed worldwide between 1995 and 2012 (Blanc-Brude and Ismail 2013b).

Furthermore, within the project finance universe, the vast majority of equity and debt instruments are privately held. For instance, infrastructure project debt can consist of loans or bonds but private loans constitute the lions' share of total private sector debt (Yescombe 2002).

Project bond financing has always played a minimal role in project finance globally. In North America, the market in which they are the most used, cumulative project bond issuance between 1994 and 2013 amounts to a mere 5% of the total deal flow (see Blanc-Brude, Hasan, and Ismail 2014). The figure is much lower in other regions. Thus, it is fair to say that the immense majority of infrastructure project financing is private loan finance.

Likewise, project finance equity investments are almost always privately held by project sponsors (construction companies), infrastructure asset managers, or directly by long-term investors.

Such instruments are genuinely long-term. They have long maturities, including on the equity side since projects always have a finite life. In effect, the maturity and duration of infrastructure project finance equity tends to be much longer than that of project debt.

Project debt is structured to have a 'tail' i.e. the post-maturity period in the project's life which can serve to to recoup potential losses during the loan's life. They are also highly illiquid and thus seldom traded.

### *4.1.2 Project finance corresponds to well-defined financial instruments*

A second reason to focus on project finance springs from the fact that, contrary to the ill-defined notion of 'infrastructure', it benefits from a clear and universally recognised definition since the Basel-II Capital Accord.

"Project finance is a method of funding in which investors look primarily to the revenues generated by a single project, both as the source of repayment and as security for the exposure.

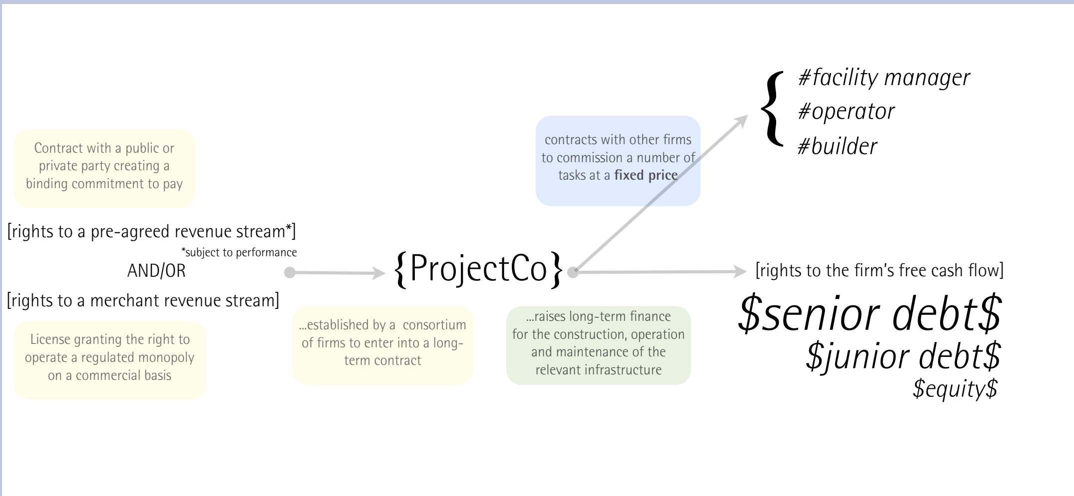
In such transactions, investors are usually paid solely or almost exclusively out of the money generated by the contracts for the facility's output, such as the electricity sold by a power plant.

The borrower is usually a Special Purpose Entity (SPE) that is not permitted to perform any function other than developing, owning, and operating the installation.

The consequence is that repayment depends primarily on the project's cash flow and on the collateral value of the project's assets." (BIS 2005)

Hence, by focusing on project finance, we capture the bulk of private infrastructure financing and gain a clear definition of infrastructure instruments at the underlying level.

Figure 1: A project finance SPE: Well-defined, investable infrastructure assets



### *4.1.3 Project finance is a unique form of corporate governance*

Finally, project financing can be expected to create financial instruments that have unique characteristics compared to other assets already available to investors.

Project financing is a specific model of corporate governance designed to optimally constrain the behaviour of the firm's managers with the use of leverage, and create enforceable decade-long commitment mechanisms, thus making long-term investment possible without a large corporate having to put their balance sheet at risk.

As figure 1 illustrates, project financing amounts to investing in a single-project firm or SPE with a pre-defined lifespan. Before the financing decision can been taken, this SPE has to demonstrate its financial viability with a high degree of probability. Schematically, two inter-related types of financial claims are created, splitting the free cash flow[12] of the project between a senior, fixed-rate claim on the one hand (debt), and subordinated, a variable rate claim on the other (equity).
Financial leverage thus plays an important role in project finance. In a recent review, we report that senior leverage[13] in infrastructure project finance consistently averages 75% between 1994 and 2012, irrespective of the business cycle, and can be as high as 90% (Blanc-Brude and Ismail 2013b).

We and others have argued that the high leverage typically observed in project finance should be interpreted as a sign of low asset risk (Esty 2003; Blanc-Brude 2013) i.e. lenders agree to provide most of the funds necessary to carry out the planned investment without further recourse or security because the probability of timely repayment is considered to be very high.

Thus, the form taken by non-recourse project financing clearly suggests that such structures and their associated senior and junior capital tranches have more in common with one another than with other types of assets and may contribute positively to traditional multi-asset class portfolios.

## 4.2 The role of definitions and models to benchmark long-term investments

Of course focusing on project financing can seem too restrictive as it leaves out a number of private investments in what can perfectly legitimately be labelled "infrastructure" (e.g. some airports). However, the task at hand is not to document the performance of any investable infrastructure asset but to understand the characteristics of sufficiently large and homogenous groups of assets that can be statistically expected to exhibit a certain risk/return profile over a given period of time.

In this respect, project finance provides us with an ideal type of what infrastructure investment is supposed to be (i.e. the investment narrative introduced in section 1 as well as a tractable and consensual model of underlying cash flows, which is necessary to benchmark long-term investment. We return to both point below.

### *4.2.1 Ideal-type infrastructure investment*

Project finance can be considered to be an ideal-type of infrastructure project cash flows dynamics. Of course, other forms of corporate governance can also lead to genuinely long-term investment in infrastructure projects, however they are less clearly related to the infrastructure investment narrative: they tend to mix project revenues with other income from equipment sales, technology licensing and services.

Their long-term behaviour is also harder to predict. For example, the management of a large water utility with a sizeable project portfolio held on balance sheet could decide to branch out into new media to leverage its otherwise predictable net operating cash flow, thus completely changing the risk profile of the firm's equity.

12 or net operating cash flow.

13 The ratio of senior debt to total investment.

Thus, while investors may legitimately consider such firms to be "infrastructure" even through they are not project finance vehicles, they only label them as such because they expect them to behave like a collection of project finance SPEs. In other words, the project finance debt and equity (promises of timely debt repayment and of regular dividend payouts, with a high probability and for several decades) are indeed the reference instruments.

To expect the same investment profile from a firm active in the infrastructure sector but without the ringed-fenced SPE structure found in project financing, requires making numerous assumptions about the behaviour of the firm's management that are otherwise explicit and well-documented in non-recourse project finance, especially the level and expected evolution of balance sheet leverage and the use of debt covenants to constrain the behaviour of the firm's managers.

### *4.2.2 Tractable,predicable models of the firm*

Instead, project finance provides us with a readily tractable investment model: a firm created to realise a single investment project and repay its debtors and investors throughout its life according to a pre-agreed plan. By statutes, this firm is not allowed to engage in any other activity or to raise capital for other investors or borrow from other lenders.

In project finance, the firm is the infrastructure project and its financing includes a stringent plan to execute a set list of tasks at certain dates for the next 20 or 30 years. Each of these tasks is governed by a contract allocating risks such as construction cost overruns or revenue volatility to a well-identified party, which may or may not be the investor or lender.

Not only is there no other equivalent in corporate governance, but a population of project SPE structured roughly along the same lines can be expected to exhibit a reasonably homogenous average behaviour.

With long-term investments, we cannot observe (unique) market prices. In the extreme case, infrastructure equity and debt can simply be held to maturity from their date of origination and never be traded. Consequently, building a benchmark requires assuming the homogeneity of a group of instruments a priori i.e. before making any observations and confirming or rejecting this assumption once observations can be made a posteriori.

In other words, in the absence of sufficient representative market data, we cannot do without valuation models. In the case of long-term investment in infrastructure, we must make explicit use of models to formalise our expectations about the performance of debt and equity instruments.

The choice of definition is thus a function of the empirical problem at hand: as we argued in section 3, we know that even with the best efforts to aggregate available data on infrastructure project cash flows today, empirical evidence will remain limited in scope and in time.

We must then rely explicitly on cash flow models to represent the totality of the underlying cash flow process that determines the expected value of infrastructure project debt or equity.

If cash flow modelling plays a central and necessary role in the valuation of long-term investments in infrastructure, the choice of definition of the underlying instruments must allow for the formulation of a tractable and uncontroversial cash flow model.

Project finance allows the formulation of such models for generic types of infrastructure projects, which can be calibrated using available data. In other words, despite the paucity of available data, project finance provides us with an opportunity to anticipate future performance that is seldom found in the case of other long-term instruments.

To conclude, we note that financial instruments other than project finance debt and equity could also be used to define the underlying asset in a benchmark of long-term infrastructure investment. Such instruments would need to meet three criteria:

- There should be a good reason to believe that such assets have a different investment profile than existing partitions of the investment set i.e. corporate bonds, private equity, etc.

- Such assets should exist in large enough quantities to be relevant at the strategic asset allocation level for a typical investor. It is not clear that an asset pool that would, for example, represent less than 1 percent of assets under management, requires an investment benchmark.

- It should be potentially accessible to investors in sufficiently granular portfolios that some degree of diversification and an exposure to the average asset should be possible.

To our knowledge, infrastructure project finance debt and equity are the main types of financial instruments that meet all three criteria today.

Next, using non-recourse project finance as our definition of both infrastructure debt and equity instruments, section 5 introduces the most recent advances in data collection, cash flow modelling, valuation and risk measurement applied to long-term infrastructure equity and debt.

## 5 Recent advances

The first step of our roadmap towards the creation of benchmarks for long-term investment in infrastructure is to define underlying financial instruments. In section 4, we argued that non-recourse project finance debt and equity are the most relevant financial instruments for this purpose. In this section, we highlight the findings of two forthcoming EDHEC-Risk Institute publications aiming to implement the second step on the roadmap: designing adequate and transparent valuation and risk methodologies.

First, we highlight the empirical issues characterising the collection of long-term infrastructure equity and debt cash flow data and how they may be addressed methodologically.

Next, we discuss the challenges of valuing long-term equity investment in infrastructure projects and describe a simple and intuitive approach. The last section offers similar insights and conclusions regarding infrastructure debt instruments.

### 5.1 Addressing data paucity

Measuring the performance of infrastructure debt and equity investments requires empirical observations. However, long-term investments such as these are characterised by a significant paucity of available data.

First, limited cash flow data currently exists. It is scattered amongst numerous private investors and little or no effort has been made to construct a database of these cash flows. Today, this database must be built, and this is one of the steps on the roadmap.

Nevertheless, *even with such a database*, empirical observations about infrastructure equity and debt cash flows will remain limited in the cross-section and truncated in time.

First, infrastructure cash flow time series are incomplete: by definition, the immense majority of infrastructure projects currently investable are far from having reached the end of their life.

For instance, say that an infrastructure project has a 30-year life, how many projects and their cash flows can we obverse today that were financed in 1984? The answer is that few such projects existed at the time (e.g. oil & gas rigs and coal-fired independent power projects), that such projects have little to say about the kind of infrastructure investment that pension funds and insurers might consider today, and that the data records have not been kept!

Hence, most of these cash flows remain in the future for which very little, if any, comparable investments currently exist.

Indeed, in the cross section, the type of infrastructure projects that have been financed over the past few decades has evolved and is not necessarily representative of investment opportunities today.

In Europe for instance, certain types of projects only exist in certain countries and have been financed during a given time period. This is because the decision to build new infrastructure is the result of a procurement process which goes through public policy phases: for example, the 1990s were characterised by the financing of new road projects in Eastern Europe, while the 2000s mostly led to the development of social infrastructure in the UK and later France, as well as road projects in Spain and Portugal, with real and shadow toll mechanisms respectively.

Hence, what is representative of investable infrastructure in the cross-section changes with time, especially if one assumes that pension funds and insurers are buy-and-hold investors.

Moreover, the number of observations remains low for the purpose of measuring cash flow volatility. Stochastic models can require large amounts of data points to populate probability distributions, but only dozens of investable infrastructure projects are created every year in the most active markets.

Instead, what *can* we observe? In the majority of cases, the only observable price information are the initial equity investment and debt originated at the date of financial close, given a risky cash flow forecast or "base case". We may also observe updated cash flows forecasts spanning the remaining life of each investments. Finally, we can observe realised equity and debt cash flows and cash flow ratios but only for a faction of existing projects' lives.

Realistically, we doubt that a bit more than a decade of observed cash flow data can be collected today (e.g. the project finance default studies undertaken by ratings agencies do not manage much longer time series). Likewise, given the private nature of such information, even with the active cooperation of a number of market participants, sample size in the cross-section will remain limited.

The second challenge is the (almost) complete absence of market valuation for projects that are invested at one point in time and are then held to maturity. While unlisted infrastructure project equity may be traded in secondary markets, it is seldom the case (little transaction data exists). The same is even more true for infrastructure project debt.

If we do no expect that enough information can be available to apply standard frequency-based statistical techniques (e.g. ordinary least square or panel regression), Bayesian inference can be preferred as an estimation approach.

Bayesian statistical inference proposes to document the existence of mechanisms and their parameters, which we believe to exist but about which not enough data is available to warrant the calculation of a p-value in the classic statistical sense,[15] which of course does not mean that the mechanism in question does not exist! The p-value really is a statement about available data, when we want to make a statement about an hypothesis given the available data (McGrayne 2011).

Thus, Bayesian inference begins from a position of relative ignorance and proposes to update our knowledge conditional on what we can observe. Jeffreys, a prominent Bayesian statistician, once remarked: "There has not been a single date in the history of the law of gravitation when a modern significance test would not have rejected all laws [of gravitation] and left us with no law." (cited in Lindley 1999 p.391)

With Bayesian inference, we attribute a likelihood function to some phenomenon. For example, the likelihood of observing n defaults within a population of $N$ loans during the first year of the loan's life is a Binomial (binary) likelihood of parameters $p$ and $N$ i.e. if N=100 loans, $p$ corresponds to the probability of default during the first year.

We then attribute a *prior* distribution to the value of the likelihood function's parameter $p$, since it is unknown and few observations exist. Since $p$ is a percentage value, it is given a Beta distribution, which can represent almost any density bounded

15 A p-value expresses the likelihood of observing a phenomenon if the underlying mechanism did not exist. Typically, frequency-based statistical results are considered to be "significant" with a high level of confidence when p-values are very small, typically 1%. This implies the ability to observe representative samples.

by 0 and 1. This *prior* distribution is given parameter values that either represent the best of our current knowledge of the mean and standard deviation of the probability of default (from a cash flow model for a generic type of infrastructure project financing) or the extent of our ignorance, for example a fifity-fifty probability of default.

As soon as we observe even a few defaults, the parameters of the beta distribution of *p* can be updated (in this case, using simple calculus) and our new current knowledge be captured by the so-called *posterior* distribution of *p*. In forthcoming research, we find that even a limited sample can lead to significance reduction in the variance of the parameter estimate i.e. in the extent of our ignorance of this parameter.[16]

Because we use well-defined underlying instruments with a tractable cash flow model (see section 4 on defining long-term infrastructure investment), we can first build a prior distribution of the cash flow process at each point in the lifecycle of generic infrastructure projects, given the state of our knowledge about how infrastructure projects are structured and expected to behave.

Next, using available data about realised states of the world and revised cash flow forecasts, we can update this *a priori* knowledge, using Bayesian inference techniques, and arrive at *posterior* probability distributions of infrastructure equity and debt cash flows.

Given the nature of the empirical question and the state of our knowledge, **this is the best result that can be achieved.** This set up actually allows for rapid and effective learning and we believe that setting the problem of long-term investment in Bayesian terms is both appropriate and more powerful than using frequency-based approaches which, even with larger samples, can suffer from significant issues.

## 5.2 Approaching infrastructure equity valuation and performance measurement

### *5.2.1 The challenge*

In a forthcoming paper (Blanc-Brude and Ismail 2014), we propose a methodology to value investments in unlisted infrastructure project equity on a buy-and-hold basis. We aims to use a limited amount of input data (mostly cash flows) and to apply this methodology at different points in time i.e. at the start of a new project and as the project happens and goes through its lifecycle, typically 25 years or more, both looking forward (assessing current value) and backward (assessing past performance).

In this context, most methods applied to other illiquid types of equity investments such as private equity and real estate are inadequate. First, as discussed above, self-reported nat asset values (NAVs) are considered to offer limited reliability and are unlikely to have been computed with comparable assumptions about cash flow expected values or discount rates.

The repeat sales approach applied to PE (Woodward 2004; Cochrane 2005; Korteweg and Sorensen 2007) is inadequate because very few transactions involving infrastructure project equity stakes can be observed in secondary markets.[17]

Indeed, we need to document the value of infrastructure project equity not only across different types of projects (e.g. by revenue risk profile as discussed in section 3) but also at every point in a project's lifecycle, from the construction phase, to the different operating and decommissioning phases. It is not the case that enough secondary market transactions can ever

16 The likelihood of being in default at the next period is also defined as a function of the default state at the current period. A cash flow model can thus be build as a dynamic Bayesian Markov Chain.

be observed across a large enough sample of projects, in the cross-section and time series.

Public-market equivalents (PMEs) using the cash flows into and out of PE funds as if they represented buying and selling a public index (Kaplan and Ruback 1995; Ljungqvist and Richardson 2003; Kaplan and Schoar 2005; Phalippou and Gottschalg 2009) are self-defeating in our case because they do not allow observing the covariance with market returns (beta) of private equity investments but rather assumes this can be proxied by an index of choice. If the implied beta is lower than the true beta, the measured outperformance is necessarily overstated (Woodward 2004).

Indeed, such market proxies are unlikely to be very useful in the case of infrastructure project financing. Identifying a peer-group of listed firms for a Leveraged Buy-Out deal in a given industrial sector with clear listed equivalents (e.g. retail or pharmaceuticals) may be reasonable, notwithstanding the necessary assumptions on sector specific leverage and the beta of the sector's debt.

But since our premise is that project finance creates access to a new and unique beta, picking a market beta from a universe of traded stocks answers the question a priori, controlling for leverage, which is trivial.

An extension of the PME approach proposes that if PE funds are valued fairly, the ratio of the present value of inflows to the present value of outflows should equal unity. Market betas and alphas can thus be extracted iteratively from inflows and outflows into PE funds from the point of view of the limited partner (see Driessen, Lin, and Phalippou 2012; Ang et al. 2013).

This new strand of the literature on PE aims to explain a given measure of PE performance as a function of public market movements i.e. instead of assuming a beta value, they propose to estimate the beta of PE fund cash flows.

But because of the documented bias in PE performance reporting discussed above, this approach only uses samples of PE funds for which all cash flows can be observed i.e. that have reached maturity and have effectively returned their funds to investors.

While this last approach is much more directly relevant to the estimation of the relative performance (beta) of long-term infrastructure equity investments, it also relies on the kind of dataset that we do not believe can be obtained for undeerlying infrastructure project equity today, for the reasons that we highlighted in the previous section.

Indeed, what we can observe in the case of infrastructure project finance equity stakes is limited to:

i. An initial investment value at the time of financial close

ii. A base case dividend forecast also at the time of financial close

iii. Revisions of the base case dividend forecast after financial close

iv. A (truncated) series of realised dividends, usually covering less than half of all expected dividend payouts

In other words, the challenge is to estimate the performance of an asset that is lumpy, held to maturity, for which most cash flows remain to be observed, with (almost) no market prices, limited observed cash

17 Unlike venture capital (VC) or other PE investments, infrastructure project finance does not lead to multiple financing rounds or frequent public offerings (IPOs).

flows in time series and limited granularity in the cross-section.

Finally, we know that not all long-term investors will attribute the same value to the same infrastructure equity stake. In this case, **markets can be considered incomplete** for exogenous reasons (there is no easily identifiable portfolio of traded securities which replicates the payoff of the asset, even though this may change as infrastructure investment products develop), as well as endogenous reasons (transaction costs are high).

In an incomplete market setup, individual investors arrive at different valuations of the same financial instrument: there is no single set of discount rates of expected payoffs. Instead, individual investor risk preferences partly explain their cost of equity for a given expected payoff.[18]

Hence, the proportion of infrastructure equity returns that cannot be explained by objective systematic factors must lie within a subjective range of discount rates, determined by individual investors attitudes towards risk, liquidity, inflation, duration &c. For instance, investors' valuation of the diversification benefits of infrastructure is a function of the size of their allocation to infrastructure equity.

Likewise, the oft-mentioned illiquidity premium that characterises long-term investment is not uniquely priced i.e. investors with different preferences require different levels of liquidity premia *for the same asset.*

### *5.2.2 Approach*

The challenge described above is not just an empirical problem. Rather, it goes at the heart of long-term investment in infrastructure: assets with delayed payoffs determined by a set of future circumstances that can only partially be predicted by past observations.

Thus, illiquidity and the absence of frequent or even unique market prices, combined with long repayment periods that go beyond the length of currently available data time series means that we cannot value infrastructure equity without a cash flow model.

That is also why a clear definition of underlying instruments is necessary: without it, the relevant cash flow model cannot be built.

Our proposed approach consists of three stages: first we estimate the distribution of cash flow to equity at each point in time in the life of a typical or generic infrastructure project using a model calibrated with available observations.

Next, this chain or series of expected dividend values and volatilities is combined with the range of observed initial investments made in this category of equity cash flow processes to derive the implied discount rates of investors.

Finally, the combination of expected dividend estimates and implied discount rates allows the derivation of a number of (conditional) performance measures.

18 For example, consider a basket of infrastructure equity in infrastructure projects with a well-documented duration and inflation hedging property. Imagine two potential investors: an insurance firm with a duration mismatch but no inflation-linked liabilities and a minimum liquidity constraint, and a sovereign wealth fund with a mandate to preserve the purchasing power of national savings and a very-long investment horizon. With no duration or liquidity constraint, the SWF is only interested in investing in the inflation-hedging property of these assets. Conversely, the insurer values the opportunity to invest in assets with a duration but must also price its liquidity constraint and, in this case, has no particular preference for inflation hedging. Both buyers are unlikely to offer the same price and there is no reason why their valuation should converge, except incidentally.

### *5.2.3 Modelling and calibrating a generic equity cash flow process*

Our proposed approach takes advantage of the fact that project finance is well-documented at the time of investment to group infrastructure equity investments that are expected to correspond to a homogenous cash flow process.

For example, we can make groups of homogenous infrastructure project finance equity investment by type of SPE financial structure (e.g. initial leverage, amortisation profile, tail length[19]).

Indeed, we only observe projects for which the decision to lend has already been taken by the relevant lenders and this can be interpreted as a partial price signal (lenders have read all the documentation and, along with Esty (2003), we posit that in project finance, the choice of financial structure signals asset risk). Table 2 and figure 2 provide an example.

Additionally, we can group infrastructure equity investments by types of contractual features, as banks do before they decide to lend i.e. projects can be categorised by type of revenue risk (merchant, partially contracted or fully contracted income) as well as supply risk (e.g. the degree of price or volume certainty of fuel supply) or types of public counter-party risks (municipal vs. sovereign).

Using these ex ante categories, generic cash flow models can be built using Monte Carlo methods. This simulation provides us with prior distributions (before observing any data) of the probability of the equity cash flow being in different states at each point in time.

For example, the model produces a probability that the project be in a state of default or "lock-up" (close to default and in breach of a debt covenant), in which case equity cash flow is zero in that period. Conditional on not being in default or lock-up, the simulation also produces a distribution of the value of dividends payable to equity holders at each point in time.

The result is a measure of expected cash flows and cash flow volatility in each period. It is modelled as a dynamic Markov chain i.e. in each state (e.g. default, lock-up or payment state) we compute the probability of moving to any other state at the next period given the current state. We also compute the expected value and volatility of dividends in each state for each period.

Once a prior (simulated) distribution of dividends has been obtained, it can be calibrated using available data for this type of generic project and for the number of years for which it is available. Using Bayesian inference techniques, we update our knowledge of the probability of transiting to any given state (default, lockup, payment) given the current state for an equity investment in the relevant group of projects, as well as the distribution of expected dividends themselves.

As more data become available, our knowledge of equity cash flow dynamics of a given type of infrastructure project improves and our estimates of the stochastic parameters becomes more precise.

Faced with the empirical problem initially identified (no market prices and limited observable data) we can still construct expected equity cash flow dynamics by combining our knowledge of how infrastructure project finance is structured and thus likely to behave on average, with as much data as can be obtained at this early stage in the data collection effort.

19 The amount of time between the maturity of the project debt and that of the equity tranche.

### *5.2.4 Implied discount rates*

To derive the (un-observable) discount rates implied by the investment decision made by equity investors, we assume the existence of a linear relationship between the term of structure of investor's discount rates and the characteristics of equity cash flows, namely, dividend volatility in each period.

In other words, the initial investment decision, given the base case equity cash flows implies the volatility of the base case. Hence, it also implies the investor's term structure of discount rates of this investment opportunity at that time.

While their initial valuation need not always be correct since investors may fail to forecast cash flows accurately, these investment decisions and implicit valuations are a) the only ones available, b) can be expected to be informative, if not correct, on average for a homogenous cash flow process.

Hence, observing a series of individual investments in what we consider a priori to be the same underlying equity cash flow process, and given our current knowledge of the volatility of this process, we can find the term structure of discount rates that minimises the distance between initial investment values and the present value of expected cash flows.

This is solved as a nonlinear fitting problem which considers a set of projects base cases and consists of computing the difference between the initial investments value (observed values) and the expected value of dividends (future cash flow estimates) discounted by an estimated term structure or discount rates.

Starting with an initial "seed" or construct for a term structure, the fitting procedure advances in an iteratively to find an optimised term structure or discount rates function that minimises the difference between the observed initial investment value and the implied present value of the expected cash flows, over the whole set of projects base cases i.e. the procedure minimises the difference between what we actually observe and what we would observe if all investors valued the set of risky cash flow process in the same manner (if they had identical preferences and utility function).

Finally, since individual investors put a different initial value on the same risky cash flow, their true individual discount rate must diverge somewhat from the average estimate. This is embodied by the error term in the fitting problem described above.

The range of individual valuations can be represented by considering the maximum divergence between the present implied by the estimated discount rates, and the actual initial value paid by each investors. The maximum percentage error in both directions and the difference in the implied discount rates that produce a better fitting of the present value of these two extrema with the discounted expected dividends value, gives an upper and lower bound to the implied term structure of discount rates.

Figure 3 provides an illustration of the average and upper and lower implied discount rates for the same type of infrastructure project than the one described in table 2, using a (simulated) range of investment decisions and the model's predicted equity cash flow volatility.

### *5.2.5 Performance measures*

Once the implied term structure at time t has been derived from a range of observed investors' investment decisions in a given cash flow process, a new value of the project equity at t+1 can be computed. That is, the implied discount rate at t+1 is treated as the **rate of return** at that time conditional on the implied valuation (discounting) of the remaining T-(t+1) cash flows i.e. conditional on the information available at that time.

At the next period, the implied term structure is revised using the information that has become available at time t+1. This new view on cash flow volatility during the following periods i.e. after updating the cash flow model, gives a new conditional expectation of dividend payouts in each period.

Estimated period returns thus remain conditional on the expected value and volatility of cash flows during the rest of the project's life. As more time periods become observable in a population of projects, and the knowledge of the relevant cash flow process improves, this conditionality introduces less and less variability in current valuations and period return estimates. Reported period returns will only become unconditional once the project has reached the end of its life.

Other return measures that can be computed at this stage include the **yield-to-maturity** (since project finance equity has a fixed term) and the **returns achieved in excess of the investment base case** recorded at financial close.

In Blanc-Brude and Ismail (2014), we also show that our measure of expected cash flows combined with the implied discount rate of equity investors can be used to calculate an **expected loss** value and various extreme loss measures such as **value-at-risk and expected shortfall.** Figures 4 and 5 provide an illustration for the case described in table 2.

### *5.2.6 Conclusion*

To conclude on the topic of measuring infrastructure project finance equity performance, in a forthcoming paper (Blanc-Brude and Ismail 2014) argue that by partitioning the investable universe of infrastructure projects with tractable cash flow models characterised by well-documented parameters – such as initial leverage, amortisation profile, and typical average debt service cover ratio throughout the project lifecycle – we can apply Bayesian techniques and elicit the prior distribution of a stochastic cash flow to equity process that can subsequently be updated with empirical observations as they become available.

Thus, using a minimum amount of input data i.e. observing initial investment values, base case and revised equity cash flow forecasts even for a limited number of projects (per generic type), as well as actual dividend payouts even with truncated time series, we can derived full time series of discount rates.

These rates of return belong to a range indicating the highest and lowest valuations made by individual investors given their risk preferences, which we also calculate. From there, we can also compute period rates of return and a series of risk measures.

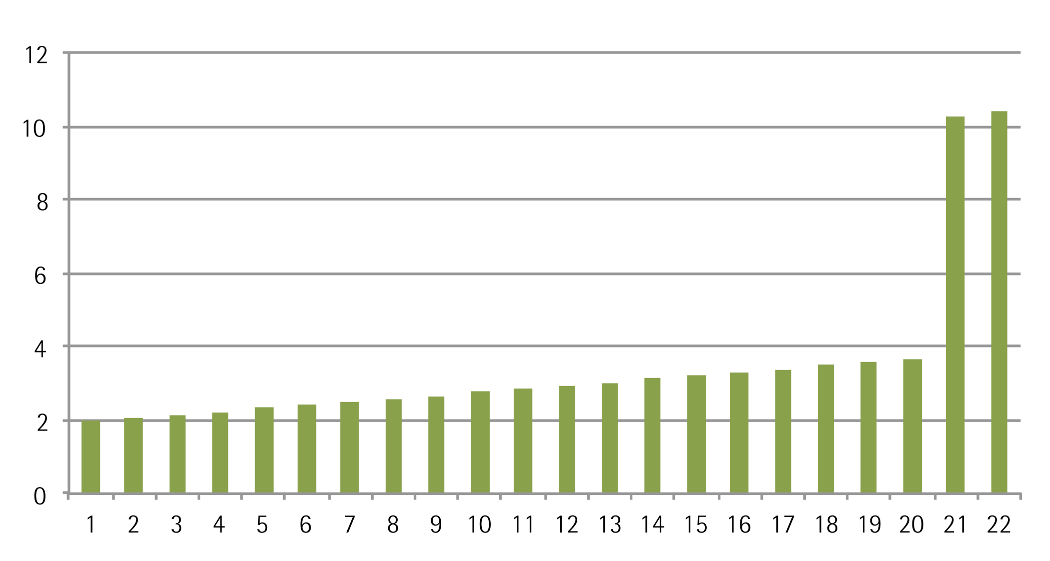
Recognising that these results remain conditional on available information at the time, and on the initial segmentation of the unlisted infrastructure project equity universe into generic project types aiming to represent a single underlying cash flow process, we show that it is possible to build the kind of performance measures that can inform the portfolio construction and, eventually, the asset allocation process, for such highly illiquid and seldom traded instruments.

We also find that calibration using even limited datasets leads to substantial variance reduction for the parameter-estimates. It other words, the learning potential from a database of project equity cash flows combined with Bayesian methods is very significant and immediate even without large samples.

Table 2: A generic "economic infrastructure" project with commercial revenue risk i.e. a growing and increasingly volatile debt service cover ratio

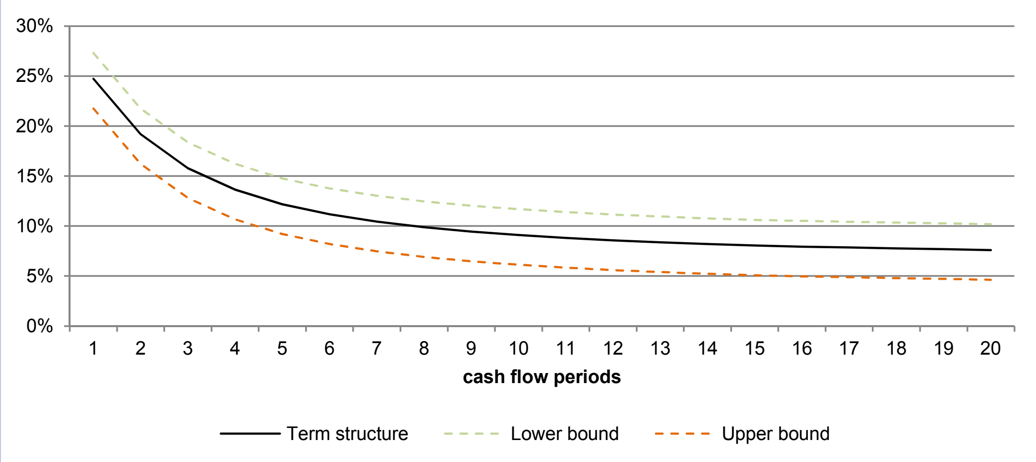
| Variable | Level |
|---|---|
| Generic project | |
| Total investment | 100 |
| Financial structure | one senior debt tranche and one equity tranche |
| Leverage at time 0 | 75% |
| Debt ammortisation profile | Constant at 6% |
| Debt maturity | 20 |
| Project life | 22 |
| DSCR from time 0 to maturity T | 1.3 to 1.6 |
| Equity lock-up threshold | 1.1 |
| Assumptions | |
| Project free cash flow distribution | Lognormal |
| DSCR volatility at time 0 | 0.04 |
| Change in DSCR volatility at t+1 given information available at time 0 | +0.1% |
| | |

Figure 2: Base case equity cash flows (mn)




Source: Blanc-Brude and Ismail (2013b)

Figure 3: Implied discount rate term structure and bounds, annual periods




Source: Blanc-Brude and Ismail (2014), forthcoming

In the next section, we present our approach to value the illiquid debt found in infrastructure project finance.

## 5.3 Approaching infrastructure debt valuation and performance measurement

### *5.3.1 The challenge*

The difficulties posed by the valuation of infrastructure project finance debt are different than in the case of equity cash flows and require an approach that takes into account its unique characteristics. The main remarkable characteristics of project finance debt are the following:

Observable nature of the underlying: Unlike traditional corporations that often have tangible and intangible assets, the assets of project finance SPEs solely consist of their future cash flows available for debt service (CFADS), which can be monitored either directly or by monitoring the debt service cover ratio (DSCR).

Debt covenants: Debt covenants such as non-financial default triggers, reserve accounts, cash sweeps, and clawback provisions can change the timing and amount of cash flows, and can considerably increase or decrease the risks involved in project finance debt investments.

Step-in options: project finance debt maturities are usually shorter than the maturity of the underlying project, and the cash flows in the period between the two maturities (often referred to as the tail of the project) serves as a security for the debt investors. Moreover, the projects are typically highly leveraged, and debt holders have greater control rights.

Therefore, during financial distress, debt investors can step-in to renegotiate the debt schedule and recover their losses. This step-in option adds an endogenous dimension to recovery rates in project finance debt.

Refinancing option: Refinancing can occur if the cash flows to the project company reach a sufficiently high level, and the project company can replace its existing debt with cheaper debt.

Illiquid and lumpy debt: project finance debt is typically held by the original investors, and trades very infrequently, if at all.

Unhedgeable risks: Several of the risks in project finance debt investments may remain unhedgeable due to long maturities and availability of a limited number

Figure 4: Average infrastructure equity upside and downside (loss)

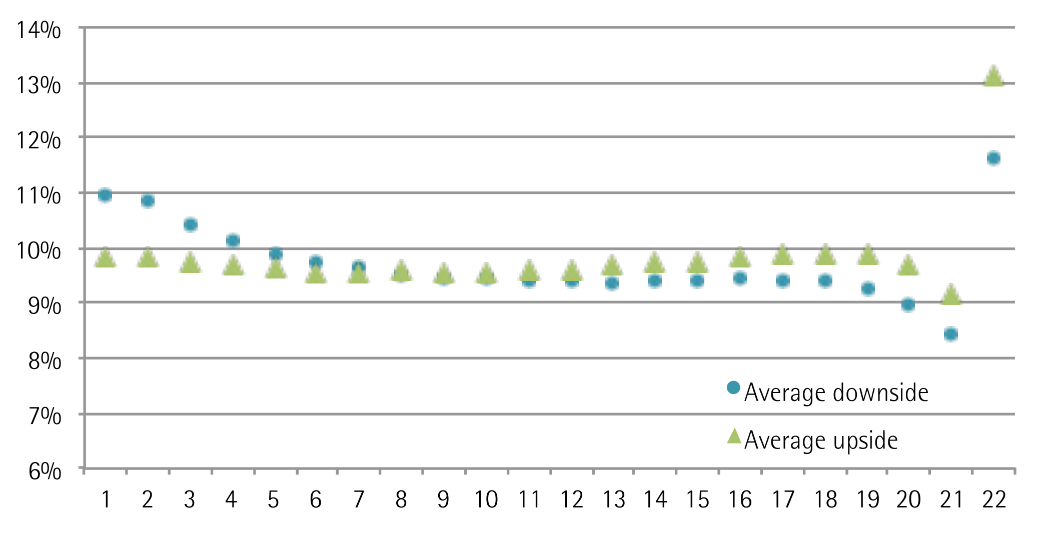
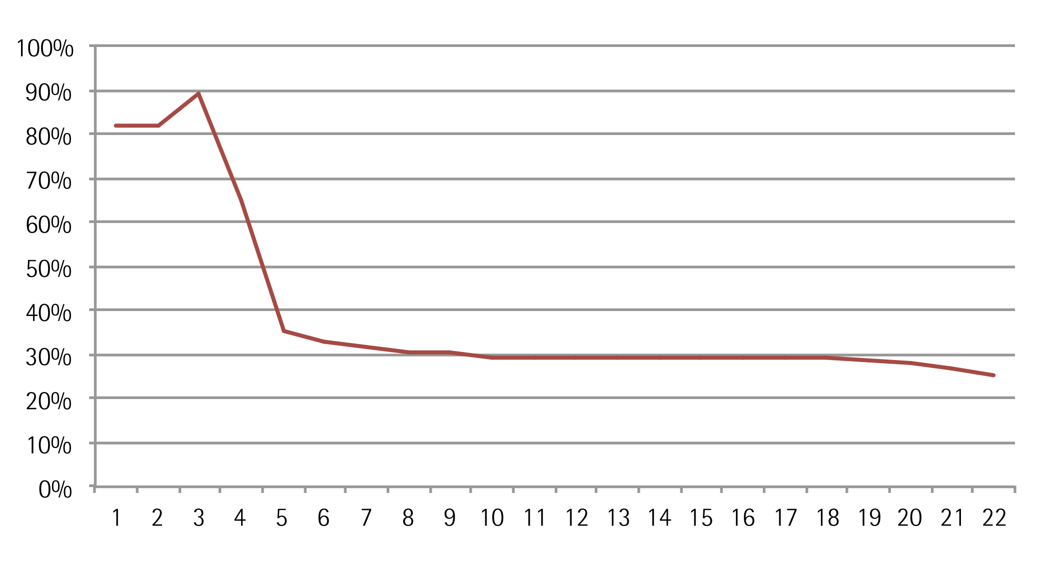



Figure 5: 99.5% one-year infrastructure equity value-at-risk




Source: Blanc-Brude and Ismail (2013b)

of projects at any time. Therefore, investors have no choice but to bear such risks, and would need to adjust their subjective valuation of such risks. As in the equity case, markets are incomeplete and a range of possible valuation is possible within a given investor population.

These characteristics distinguish project finance debt from corporate debt or bonds, which tend to be more standardised, and do not share features such as reserve accounts, illiquidity, and step-in options.

Project finance covenants create significant and extensive control rights for lenders in infrastructure project financing i.e. **embedded options** which have a substantial impact on recovery rates.

If these options are not taken into account, infrastructure debt valuation is likely to be off by an order of magnitude. Indeed, they are largely ignored in the current debt valuation models.

Existing models for project finance debt valuation include traditional capital budgeting methods such as net present value, internal rate of return, payback periods, and multinomial tree based option pricing models (Ho and Liu (2002), Wibowo (2009)).

In a forthcoming paper (Blanc-Brude, Hasan, and Ismail 2014), we develop a model of endogenous recovery rates to construct a valuation framework that can overcome these limitations, and incorporates the key features of project finance debt investments.

### *5.3.2 Approach*

Of course, unlisted infrastructure project debt suffers from a similar albeit slightly less acute paucity of data than infrastructure equity investments, for the reasons highlighted earlier. Moreover, the endogenous nature of credit risk in project finance implies that a limited number of actual events of default and recovery can be observed.

In this context, so-called "reduced form" models which consider credit events to be purely stochastic and rely on observing large amount of data are inadequate. Instead, structural credit risk models are a natural choice. Structural models postulate the existence of a default triggering mechanism i.e. a discrete event at the threshold between two states (default vs. no default). In other words, default events are not random amongst firms but must result from a contractual or financial breach.

### *5.3.2 Cash flow model*

Our intuition is that the debt service cover ratio (DSCR) that lenders regularly monitor in project finance can be used as a type of state variable, the dynamics of which can be sufficient to predict events of default. In Blanc-Brude, Hasan, and Ismail (2014), we show that the distribution of the DSCR at each point in the life of a project loan is sufficient to compute standard credit risk measures such as the "distance to default".

We also show that given a well documented DSCR distribution at time $t$ and the knowledge of base case debt service, we can reconstitute the dynamics of the cash flow available for debt service i.e. the free cash flow of the SPE, which is of course the underlying on which a put option is written in the classic Merton debt valuation model (Merton 1974).

As in the case of equity valuation described above, we argue that frequency-based approaches to credit risk remain inconclusive and that Bayesian inference can be used to calibrate cash flow models of generic project finance SPE and derive performance measures to the best of our current knowledge.

Indeed, despite being monitored by lenders, data from so called DSCR certificates can be difficult to obtain and is treated as private data by project lenders. As before, the majority of projects that are investable today still have many years of future cash flows to receive and it is unlikely that large samples of complete time-series of infrastructure project DSCR and base case case flows can be obatined.

Furthermore, the lumpiness of infrastructure project investments also warrants some scepticism that we may be able to observe sufficiently large samples of DSCR observations in the cross section.

We build a stochastic model of the free cash flow of the firm for well-defined partitions of the project finance universe and derive the prior probability distribution of the DSCR at time $t$ conditional on no default until that time. This distribution can then be updated with available data i.e. observed DSCR at a given point in the loan's life as illustrated by figure 6.

### *5.3.4 Dynamic renegotiation*

Next, we model the trajectory of cash flow to debt holders in every state of the world. In our model, if a default or refinancing trigger is reached, the entire remaining debt service is re-organised. Before observing such re-organisations, we model them using a dynamic debt renegotiation model taking into account liquidation costs. This model determines to what extent the debt service can be rescheduled without incurring any losses, or if alternatively, lender should take over the project (and wipe out equity investors) and find new owners.

The result is largely a matter of the size of liquidation costs and of the loan's "tail" i.e. the difference between the end of the project's life and the original loan maturity.

Typically, lenders structure projects that have more volatile free cash flow (e.g. merchant projects) with relatively less leverage (*c.75%)* longer tails spanning many years and higher and rising DSCRs (1.5 to more than 2) in order to maximise expected recovery. Conversely, in projects that have a very predictable free cash flow (e.g. social infrastructure with a guaranteed income from the public sector), initial leverage is higher (*c.*90%), DSCRs are lower (*c.* 1.2) and do not rise with time, and the loan's tail is much shorter (*c.* two years).

By capturing explicitly the endogenous nature of credit risk in project finance debt, we can account for the embedded options that step-in rights and other covenants represent.

### *5.3.5 Valuation*

Since valuing project debt implies taking into account future cash flows in different states of the world, including post renegotiation, implying actual discount rates from initial lending decisions and a measure of risk is not be possible. Instead, we arrive at a range of valuations by modelling the subjective probabilities that investors assign to future risky cash flows.

These probabilities are known as the risk neutral probabilities, and the valuation method is called risk neutral valuation, as the investor behaves as a risk neutral investor under the risk neutral probability measure (i.e. discounts the future cash flows at the risk free rate).

Risk-neutral valuation adjusts for risk aversion by assigning a lower probability to riskier cash flows, and hence decreasing their expected value under the risk neutral distribution, instead of discounting the expected values under the physical distribution at a higher discount rate – both approaches are indeed equivalent. In structural models, this risk neutralisation is done by mapping the physical probability of default to the risk neutral probability of default using a probability transform derived from the Merton model.

The probability transform decreases the physical distance to default (DD) by investors' required risk premium for one unit of risk, to obtain the risk neutral DD. The risk neutral PD is then simply the cumulative density function (CDF) of the negative of the risk neutral DD.

In complete markets, the absence of arbitrage implies that the required price of risk can be uniquely determined using traded securities as the cost of hedging one unit of risk. In incomplete markets, while the required price for the hedgable risk can still be determined uniquely as the cost of hedging this risk, not all risk is hedgable, and the no-arbitrage principle leads only to weak bounds (which can be strengthened using approximate arbitrage models) for the unhedgable risks.

Within these arbitrage bounds, different investors may demand different prices for these unhedgable risks. Hence, in incomplete markets, the mapping between physical and risk neutral distributions discussed above is not unique. The range of risk neutral distributions consistent with no arbitrage principle depends on the proportion of unhedgable risk.

Figure 6: Sample base case, revised and observed DSCRs (debt service cover ratios) for a homogenous category of project finance structure

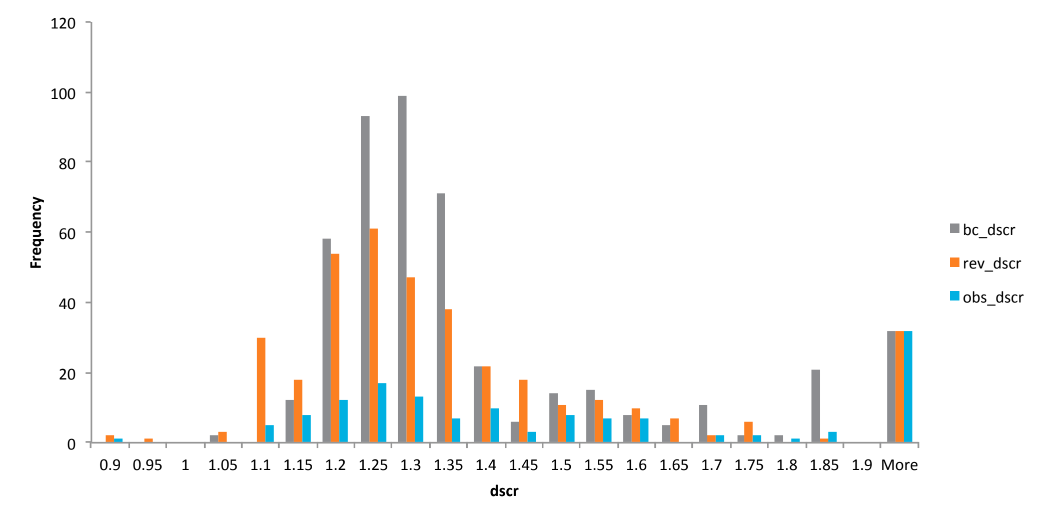
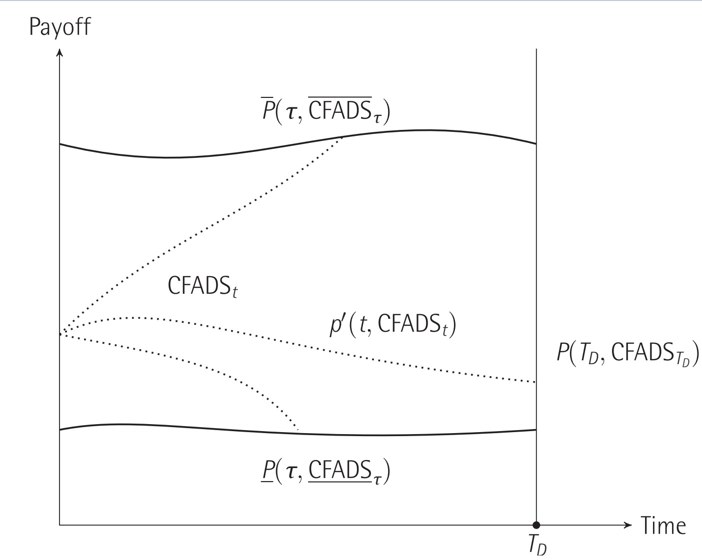



Figure 7: Black-Cox decomposition at one point in time.With renegotiations, one would need to perform a new Black-Cox decomposition everytime CFADS hits the lower boundary with updated payout functions determined through renegotiation.




Source: Blanc-Brude et al, 2014 *forthcoming*

As the proportion of unhedgable risk decreases, this range shrinks, and in the limit when all risk is hedgable, the range of risk neutral distributions converges to a unique probability measure i.e. the law of one price.

This risk-neutralisation incorporates investors' risk preferences in the distribution of future cash flows, which can then be discounted at the risk free rate to determine the value of debt.

The total value of the debt is then computed using a modified version of the Black and Cox decomposition, which splits the value of project debt into four components as illustrated on figure 7:

i. Value at the maturity date, if the firm has not been reorganised before then.

ii. Value if the firm is reorganised at some lower boundary. This can occur if the CFADS hits, say, the default threshold, and the project company reorganises.

iii. Value if the firm is reorganised at the upper boundary. This can occur if the project company refinances.

iv. Value of the payouts it will receive prior to any of the three events described above.

For each case, where the upper or lower threshold triggering a renegotiation of the debt service has been reached, a new debt schedule is derived and a new valuation conducted.

### *5.3.6 Performance measures*

Once the effects of embedded options and debt covenants on the future cash flows have been taken into account, risk measures can be computed. The combination of cash flow dynamics and debt covenants (non-financial default triggers) allows the computation of the conditional probability of default at time *t*, as figure 8 illustrates (here at time 0).

**Expected loss** can be measured as the difference between the present value of the base case debt service schedule and the present value of the projected debt payments after incorporating the effects of debt covenants and embedded options but before incorporating the effect of risk aversion. The **loss function** also allows calculating extreme risk measures such as **value-at-risk** and **conditional VaR** (expected shortfall), as figures 9 illustrates.

**Duration and convexity measures** can also be computed. The duration of project finance debt is likely to be positively correlated with the recovery rate. This is because the higher recovery rates are obtained by extending the maturity of the debt, which increases the duration.

*In other words, there is a trade-off between duration risk and credit risk in portfolios of project finance debt.*

Likewise, return measures can be computed from the valuation results. The **yield** can be calculated as the constant discount rate that makes the present value of promised debt payments equal to the value of the current value of the debt as shown on figure 10.

We can also calculate the **z-spread** (a constant spread above the risk free term structure) at time t, and **the expected (conditional) period discount** rate i.e. the discount rate under the physical measure.

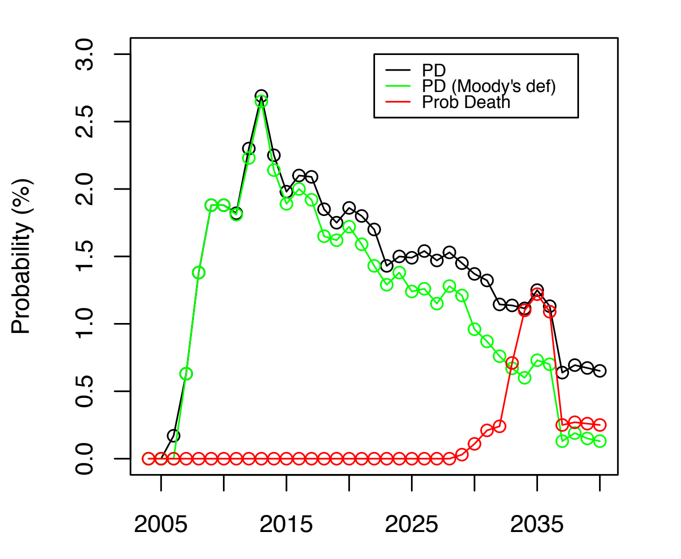
### *5.3.7 Conclusion*

To conclude, we show in Blanc-Brude, Hasan, and Ismail (2014) that the performance of infrastructure project finance debt cannot be properly modelled and measured without taking into account the endogenous nature of credit risk in project finance, that is, the active role played by lenders across the lives of these instruments to maximise recovery rates and indeed returns per unit of risk taken.

As in the case of equity stakes in unlisted infrastructure projects, these results can be obtained despite significant data limitations in the cross-section and time-series and the absence of market prices.

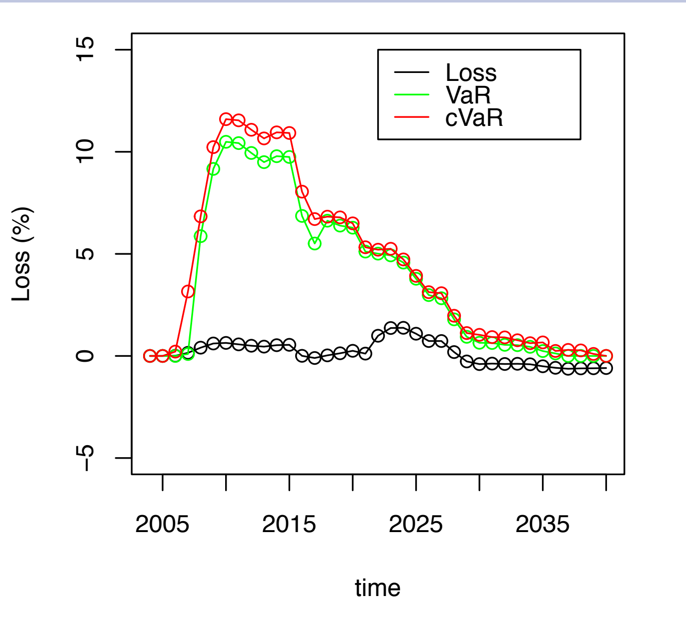
The use of a cash flow model that is designed to allow for learning through repeated Bayesian inference is instrumental in making such approaches capable of adaption and improvements. Crucially, the valuation models outlined above draw their results from asset pricing theory and provide a fully transparent methodology.

Figure 8: Simulated marginal probability of default for a homogenous project finance loan population



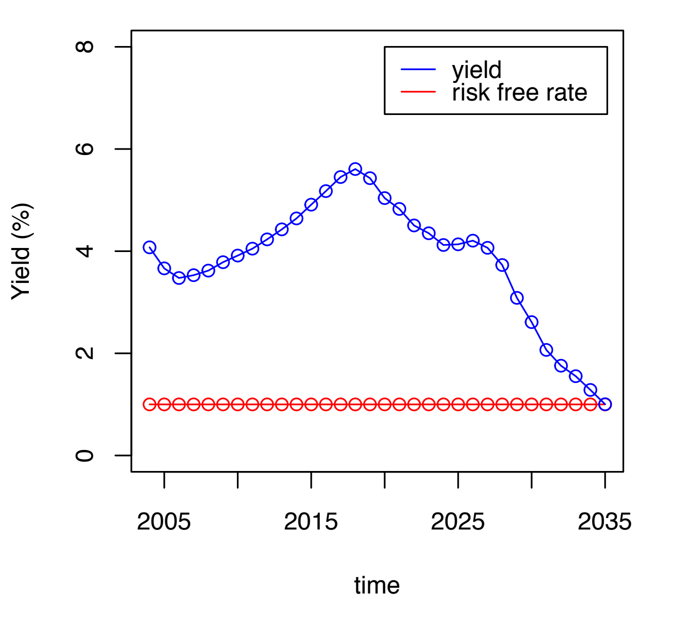

Source: Blanc-Brude et al, 2014 *forthcoming*

Figure 9: Loss given default, Value-at-Risk and cVaR in infrastructure debt




Source: Blanc-Brude et al, 2014 *forthcoming*

Figure 10: Yield for infrastructure project loans with constant (volatile) DSCR




Source: Blanc-Brude et al, 2014, *forthcoming*

## 6 The way forward

In this paper, we have argued that creating benchmarks of long-term (illiquid) infrastructure investments is instrumental to allow investors to decide whether such instruments can contribute to asset allocation decisions, and to adapt and calibrate a prudential regulatory framework that currently prevents long-term investment from taking place.

For this purpose, we propose a roadmap to address the significant lack of knowledge which characterises long-term investment in infrastructure equity and debt today.

This roadmap highlights the need to better define and document the cash flow dynamics of underlying infrastructure financing instruments, and to develop adapted and transparent valuation and performance measurement models.

It also suggests that a long-term investment benchmark is not a representative basket of existing assets at a given point in time – since such illiquid assets would not be investable at that time – but an efficient combination of homogenous building blocks that are designed to capture the average characteristics of homogenous groups of infrastructure equity and debt.

In recent publications, EDHEC-Risk Institute has begun to implementing this roadmap.

In particular, we have put forward the idea that non-recourse project finance under the Basel-II definition creates the most relevant type of underlying equity and debt to invest in infrastructure projects and embodies the expected characteristics of the infrastructure investment narrative.

As a consequence, project finance instruments qualify as reference instruments to build infrastructure investment benchmarks.

We have also developed adequate valuation methodologies, which allow for the current limited state of empirical knowledge about infrastructure investment and are designed to be updated as new information becomes available (see Blanc-Brude and Ismail 2014; Blanc-Brude, Hasan, and Ismail 2014).

The implementation of the rest of the roadmap is underway with the creation of a global database of infrastructure project cash flows and the development of a reporting standard.

Thus database will make it possible to create and produce long-term infrastructure investment benchmarks, and to calibrate the relevant prudential regulatory frameworks.

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# EDHEC-Risk Institute Publications (2012-2014)

## 2014 Publications

- Martellini, L., V. Milhau, and A. Tarelli. Towards Conditional Risk Parity — Improving Risk Budgeting Techniques in Changing Economic Environments (April)
- Amenc, N., and F. Ducoulombier. Index Transparency – A Survey of European Investors Perceptions, Needs and Expectations (March).
- Ducoulombier, F., F. Goltz, V. Le Sourd, and A. Lodh. The EDHEC European ETF Survey 2013 (March).
- Badaoui, S., Deguest, R., L. Martellini and V. Milhau. Dynamic Liability-Driven Investing Strategies: The Emergence of a New Investment Paradigm for Pension Funds? (February).
- Deguest, R., and L. Martellini. Improved Risk Reporting with Factor-Based Diversification Measures (February).
- Loh, L., and S. Stoyanov. Tail Risk of Equity Market Indices: An Extreme Value Theory Approach (February).

## 2013 Publications

- Lixia, L., and S. Stoyanov. Tail Risk of Asian Markets: An Extreme Value Theory Approach (August).
- Goltz, F., L. Martellini, and S. Stoyanov. Analysing statistical robustness of cross- sectional volatility. (August).
- Lixia, L., L. Martellini, and S. Stoyanov. The local volatility factor for asian stock markets. (August).
- Martellini, L., and V. Milhau. Analysing and decomposing the sources of added-value of corporate bonds within institutional investors' portfolios (August).
- Deguest, R., L. Martellini, and A. Meucci. Risk parity and beyond - From asset allocation to risk allocation decisions (June).
- Blanc-Brude, F., Cocquemas, F., Georgieva, A. Investment Solutions for East Asia's Pension Savings - Financing lifecycle deficits today and tomorrow (May)
- Blanc-Brude, F. and O.R.H. Ismail. Who is afraid of construction risk? (March)
- Lixia, L., L. Martellini, and S. Stoyanov. The relevance of country- and sector-specific model-free volatility indicators (March).
- Calamia, A., L. Deville, and F. Riva. Liquidity in european equity ETFs: What really matters? (March).
- Deguest, R., L. Martellini, and V. Milhau. The benefits of sovereign, municipal and corporate inflation-linked bonds in long-term investment decisions (February).
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- Cocquemas, F. Towards better consideration of pension liabilities in european union countries (January).
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## 2012 Publications


- Arias, L., P. Foulquier and A. Le Maistre. Les impacts de Solvabilité II sur la gestion obligataire (December).
- Arias, L., P. Foulquier and A. Le Maistre. The Impact of Solvency II on Bond Management (December).
- Amenc, N., and F. Ducoulombier. Proposals for better management of non-financial risks within the european fund management industry (December).
- Cocquemas, F. Improving risk management in DC and hybrid pension plans (November).
- Amenc, N., F. Cocquemas, L. Martellini, and S. Sender. Response to the european commission white paper "An agenda for adequate, safe and sustainable pensions" (October).
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- Almeida, C., and R. Garcia. Robust assessment of hedge fund performance through nonparametric discounting (June).
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