EDHECinfra

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EDHEC BUSINESS SCHOOL

Contents

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Investing should never be a guessing game

A year and a half of COVID-19 has highlighted quite starkly how essential it is for investors to be able to correctly value their infrastructure holdings. Prolonged lockdowns and travel restrictions have shown that the sector is not immune from risk, and – when entire segments of the economy are turned off for months on end – the systems that support and facilitate them will come under a variety of financial pressures. Investors have a responsibility to report a fair value of their holdings. They can't just be making guesses – and yet, for many years, a degree of guesswork has been part of the process. This is a problem that is worsened when risks are evolving so rapidly. Fortunately, EDHEC*infra* has a lot of the solutions to these issues.

In our first article, we look at how the need for frequent reporting of fair infrastructure valuations is challenging investors in unlisted assets, a requirement that is made more difficult by the paucity of data. Appraisal values are typically stale, display unrealistically low levels of volatility and are essentially backwards-looking. However, thanks to recent advances in data collection and asset pricing techniques, it is now possible to estimate the evolution of fair market prices. In this note, we show how EDHEC*infra* measures the true yield of infrastructure investments, their optimal contribution to multi-asset portfolios, duration and much more.

Our second article examines the drivers of the volatility of unlisted infrastructure equity investments. Measuring this risk is difficult because the available data is often limited to those same stale quarterly appraisals that do not reflect the current state of market prices. Our analysis uses the EDHEC*infra* database of unlisted infrastructure equity investment data, which covers hundreds of firms over 20 years and uses a new approach to measure the market value of these investments over time. Thanks to this technology, which predicts actual market prices very precisely, it is possible to measure the variability of unlisted infrastructure equity prices and to describe its fundamental components.

Our third piece looks at the next generation of data that EDHEC*infra* is making available to infrastructure investors. We have created the largest database of infrastructure investment data in the world and a state-of-the-art 'index and analytics data platform' supporting our indices, valuation metrics and discount rate tools – and soon a fund analyser tool that promises to revolutionise the way fund GPs and LPs can benchmark funds.

The penultimate article looks at the nature of infrastructure, and our TICCS® taxonomy gives investors a clear and accurate view on the true nature of their investments. The Infrastructure Company Classification Standard was first released in October 2018 and has swiftly become an industry standard that allows the definition of clear and robust investment styles in the asset class.

Our final paper explores the role of environmental, social and governance (ESG) issues in an investment context, in particular how we should gauge the relationship between ESG and the market value of infrastructure investments. This is a key question that institutional investors and prudential regulators need answered in order to integrate ESG into their financial decision-making process. However, existing ESG reporting and assessment schemes are not designed to provide answers, and this is where we are working to fill the gaps.

Armed with the right data, the right prices and the right taxonomy, investors can finally stop guessing about the value and risk of their unlisted infrastructure assets.

Frédéric Blanc-Brude, Director, EDHEC*infra*

The fair value of investments in unlisted infrastructure equity

The robustness of better data and advanced methods

Frédéric Blanc-Brude, Director, EDHEC*infra*;
Abhishek Gupta, Senior Research Engineer, EDHEC*infra*

Based on cutting-edge academic methodologies, EDHEC*infra* indexes give investors realistic prices that avoid the pitfalls of stale appraisals

As more investors consider allocations to unlisted infrastructure, the need to bring the asset class into the mainstream of risk management, asset allocation and prudential regulation is increasing rapidly. New prudential rules, the COVID-19 pandemic and the increasing visibility of infrastructure in individual retirement products have made the frequent reporting of fair infrastructure valuations all the more urgent.

Measuring the fair market value and therefore the risks of unlisted infrastructure is made more difficult by the paucity of data. Appraisal values are typically stale and do not reflect the market conditions including the latest price of risk applicable to private infrastructure. In the absence of comparable transactions, most unlisted infrastructure investments have effectively been booked at or near their historical cost.

Thanks to recent advances in data collection and asset pricing techniques, it is now possible to estimate the evolution of fair market prices for unlisted infrastructure equity investments. In this note, we report that:

- Common risk factors explain observable market valuations of unlisted infrastructure companies.
- The risk premia of these factors can be measured on an ongoing basis, as new transactions take place. Thanks to these risk premia, individual assets that do not trade but are exposed to the same factors can also be priced.
- This approach predicts transaction prices accurately within 5% of observed transaction prices and produces robust series of returns with no smoothing.

This technology allows measuring of the true yield of infrastructure investments, their optimal contribution to multi-asset portfolios, duration and much more.

Fair value matters for investors in infrastructure

Market prices are essential for investors to make sensible investment decisions.
Many investors are aware that the market price of unlisted infrastructure equity has evolved considerably over the past decade and a half, with a long period of increases in market valuations and compression of yields, which started abating in 2017 and was partly reversed in 2020 due to the impact of the COVID-19 pandemic.

These evolutions remind us that estimating fair market value is an essential aspect of investing in illiquid, unlisted infrastructure equity.

When entering the secondary market or taking part in a 'continuation' fund, a robust assessment of fair value is necessary since the price paid by investors determines their cash yield, which often attracted them to infrastructure in the first place.

Beyond the current yield, assessing the performance of infrastructure assets also requires measuring capital appreciation, including deciding when is the right time to exit investments and benefit from capital gains. This is true whether assets are otherwise booked at cost or at fair value.

Measuring fair market value is also necessary to measure and manage the risks of infrastructure investments.

Total return volatility is strongly related to the variance of market prices. The market prices of unlisted infrastructure change with dividend expectations but also with the evolution of market discount rates. In fact, with long-term cash flows, these valuations can be quite sensitive to changes in interest rates and risk premia.

Measuring these risks plays a key role in risk management and reporting, asset liability management and deciding on an optimal strategic asset allocation to the infrastructure asset class.

In this note, we show that while investors in illiquid assets like infrastructure have long been plagued by 'stale' NAVs and opaque valuation assumptions, recent innovations in asset pricing and data collection allow the robust estimation of the fair market price of unlisted infrastructure equity investments. The ability to measure market prices on an ongoing basis for the infrastructure asset class opens a new era of transparency for infrastructure.

Appraisal NAVs are stale

Investors cannot rely on appraisals to capture the fair value and the risks of infrastructure investments.
A look at the appraisal NAVs reported by infrastructure funds reveals that they cannot possibly reflect the evolution of the fair value of unlisted infrastructure

equity. This point is made abundantly clear by looking at the volatility of appraisal valuations in unlisted infrastructure portfolios: given the returns, the reported NAV volatility implies a wildly unrealistic risk-return profile, as shown in figure 1, which describes the appraisal NAVs of 13 unlisted infrastructure equity portfolios representing $23.4bn of investments in 2020.

If the risk level implied by the volatility of infrastructure appraisals in these portfolios was true, infrastructure would represent a huge risk-free arbitrage opportunity with a Sharpe ratio of 3. Even in private markets, such arbitrage opportunities cannot exist for long, let alone remain the case for 10 years. Ergo, appraisal NAVs are smooth and do not capture the fair market value of infrastructure investments.

In fact, the discount rates used to appraise these investments change very little over time and are not market discount rates. They fail to capture both the evolution of the term structure of interest rates and the latest price of risk required by market participants to invest in illiquid infrastructure companies.

The naive view on private asset valuation often includes the claim that the risks of these assets are somehow 100% idiosyncratic, and that such investments can be benchmarked using an absolute rate of return since their discount rates are not related to financial market fundamentals. This is, of course, not the case. In fact, under IFRS 13, valuations should be market-based, not entity-specific. Fair value estimates should reflect the impact of market factors, including the price of risk and the value of time.

IFRS 13 defines fair value in terms of exit price: 'the price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date'. Thus, unlisted infrastructure equity investments cannot be assumed to be worth their unadjusted NAV if market-based valuations are available. Next, we describe a novel approach to measuring the market prices of illiquid infrastructure assets.

Our approach

Despite the paucity of data available on transaction prices, it is possible to assess the fair market value of illiquid assets accurately.

1. The unbelievably smooth risk and return profile of infrastructure appraisals

	3-year	5-year	10-year
Appraisal NAV total returns	8.72%	9.65%	9.24%
Appraisal NAV total returns volatility	2.73%	2.68%	2.85%
Implied Sharpe ratio	2.79	3.19	2.86
Volatility of appraisal NAVs only	2.34%	2.48%	2.38%

Source: annual reports, NAV of assets for 13 funds of unlisted infrastructure equity representing $23.4bn of investment in 2020.

Investors have typically had to rely on stale NAVs because too few transactions were available in the unlisted infrastructure equity market to make meaningful comparisons. Infrastructure companies are quite different from one another and trade rarely. EDHEC*infra* research shows that unlisted infrastructure companies trade in the secondary market about once in their life[1] on average – ie, many never do.

Building robust comparables would require thousands of secondary market transactions for each type of infrastructure company. In a market as illiquid as unlisted infrastructure equity, this is not possible.

However, despite the low number of observations available, it is possible to reduce the number of dimensions of the problem by using a factor model.

Instead of having to observe thousands of individual transactions, the equity risk premium, EV/EBITDA ratio or any other market valuation metric can be estimated by breaking down available observations into a limited number of risk factors (eg, leverage, size, etc) and re-estimating these factor premia on a regular basis, using recent transaction values and their factor exposures.

Other infrastructure companies are all exposed to the same factors, only in different quantities. All infrastructure companies have an exposure to the size factor, the profit factor etc. Once the premium or risk premium of individual factors are estimated from actual deal values, the valuation of another infrastructure company can be derived given its exposure to these factors.

Our research shows that the most relevant, robust and persistent risk factors that explain transaction prices in unlisted infrastructure transactions are:

- Leverage (liabilities/total assets);
- Size (total assets);
- Profitability (return on assets);
- Investment (capex/total assets);
- Country risk (term spread);
- A range of control variables: business model and industrial activities according to the TICCS® taxonomy[2].

Input data

Our valuation model is calibrated using a wide and deep sample of market transactions across the different segments of the universe.

EDHEC*infra* has identified 6,800-plus

A model of input returns

Step 1 – get the risk premium (gamma) from market prices:

$$P_j = \sum_{t=1}^{T} \frac{D_{j,t}}{\left(1 + r_t + \gamma_j\right)^t}$$

Step 2 – estimate the price (lambdas) of each risk factor given the factor exposures (betas) of each transaction:

$$\gamma_j = \beta_1 \times \lambda_1 + \beta_2 \times \lambda_2 \cdots + \omega = \sum_{k=1}^{K} \beta_{j,k} \times \lambda_k + \omega$$

Step 3 – apply factor prices (lambdas) to new assets to compute their risk premia given the factor exposures:

$$\hat{\gamma}_i = \sum_{k=1}^{K} \beta_{i,k} \times \hat{\lambda}_k$$

1 Based on a sample of more than 6,800 private infrastructure companies in 25 countries.

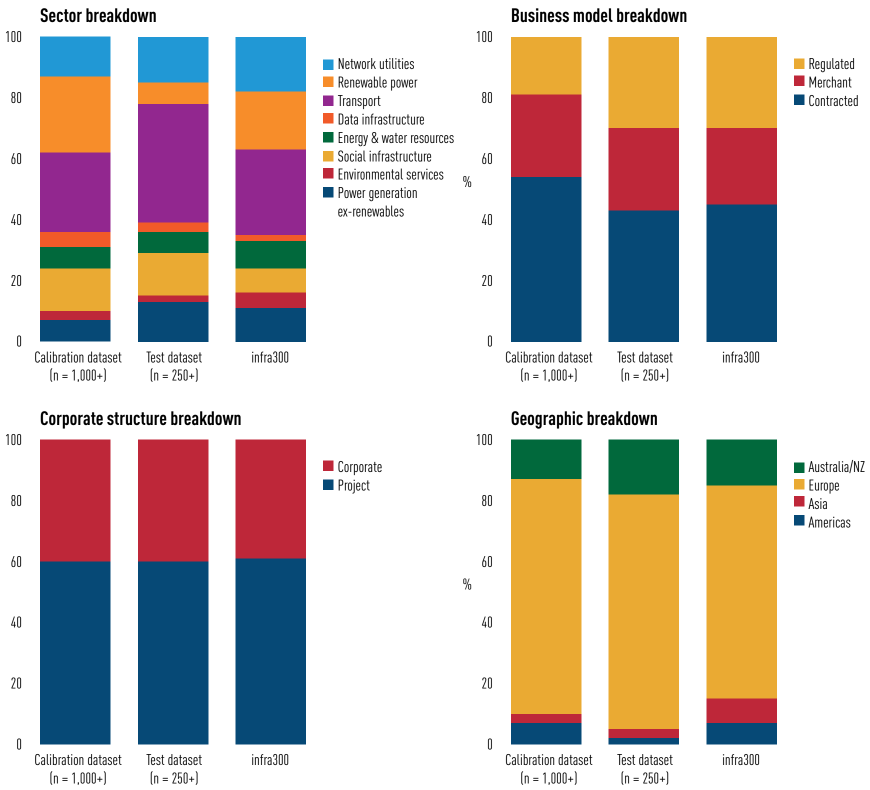
2 The Infrastructure Company Classification Standard (TICCS) is a taxonomy used to describe infrastructure investment and portfolio.

investible infrastructure companies in the 25 countries where most of the transactions take place (the 'principal' market – IFRS 13). Of these, a sample of 650-plus firms are actively monitored at a great level of financial detail to make a representative sample of this universe. These are the firms that are priced to make indices like the infra300® index.

The data used to calibrate the EDHEC*infra* model of expected returns uses 1,000-plus observed secondary market transactions of unlisted infrastructure observed over 20 years, 250-plus of which are tracked in EDHEC*infra* indices. Figure 2 shows the coverage of the model input data, the test dataset and the infra300 index weights, which represent the global investable universe.

2. Distribution of the model input price data by segment

Model calibration dataset and model test dataset vs the infra300 index weights (global market)



Source: EDHEC*infra* data from 2000–20

A robust model of expected returns and prices

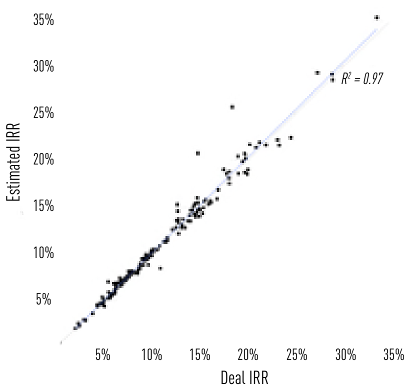
Figure 2 shows that the structure of the input data used to calibrate the risk factor model described earlier is in line with the global investible universe as measured by the infra300 index. For the 250-plus transactions that correspond to companies tracked in the EDHEC*infra* universe and for which observed secondary market prices are also available (the test dataset) we can compare observed and model-predicted valuations directly. Figures 3, 4 and 5 show a comparison between model-predicted IRRs, risk premia and EV/EBIDTA ratios with actual values for the test dataset of 250-plus observed transactions between 2000 and 2020. Model-predicted prices are accurate. The prediction error is typically within 5% of observed prices (see figures 6–7).

Figures 8 and 9 show the price to sales and price to book ratios of reported transactions against model predicted values. A perfect match between model and predicted prices would line up all dots on these plots on the 45° line. The match is imperfect for two reasons:

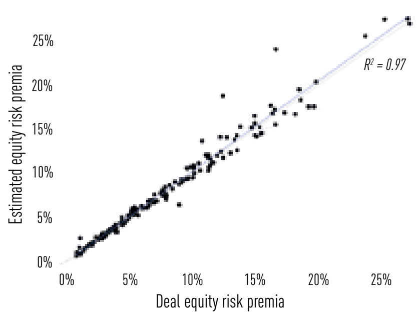
- The model predicts the average price a typical investor would pay for a given asset. In reality, buyers may pay more or less than the model-predicted average due to their own price preferences.
- The model itself is imperfect and while it captures the systematic part of the pricing in markets well, it may not embed all the assumptions or hypotheses made by buyers at the time of the transaction.

In general, however, the match is very good, as shown in figure 10: predicted valuation ratios are very close on average to observable ones. Estimated prices for all assets in the universe are thus likely to be the best

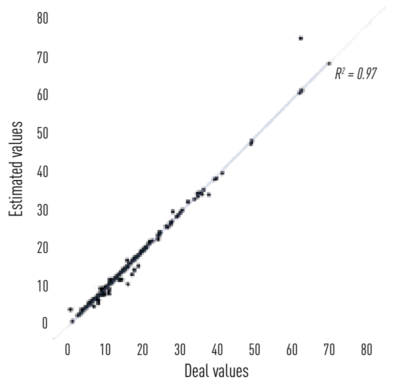
3. Estimated vs reported deal IRRs



4. Estimated vs reported risk premia



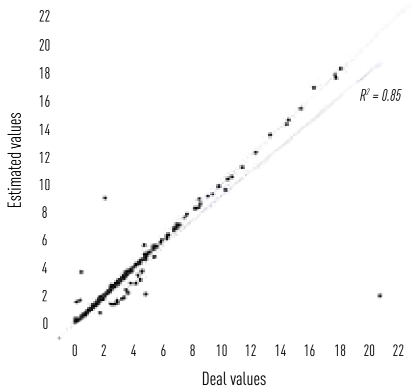
5. Estimated vs reported EV/EBITDA



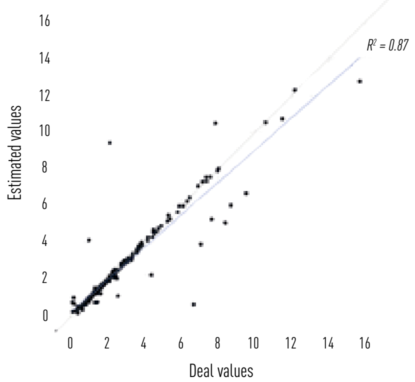
6. Quantiles of model errors

10% quantile	25% quantile	Median	Mean	75% quantile	90% quantile
–5.00%	–1.95%	–0.22%	–0.55%	1.64%	3.85%

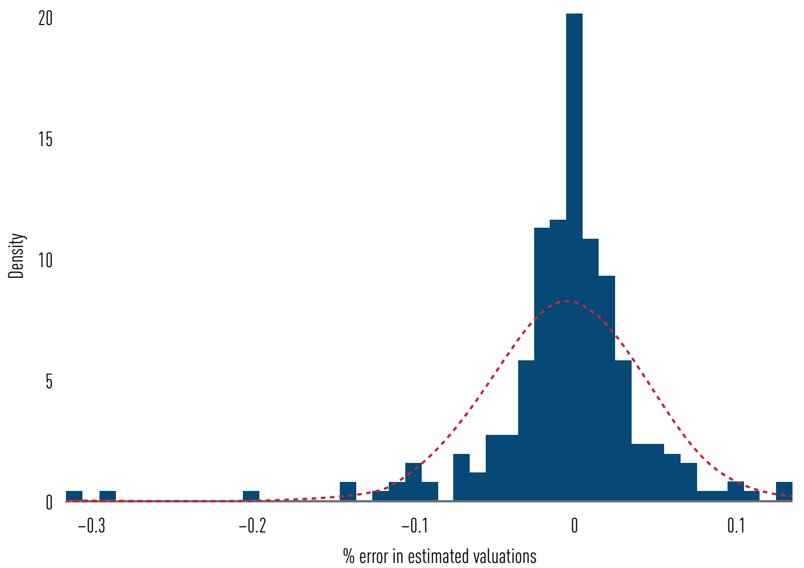
8. Estimated vs reported price to sales ratio



9. Estimated vs reported price to book ratio



7. Distribution of in-sample pricing model errors: predicted vs observed



10. Estimated vs reported valuation ratios and model goodness of fit

Ratio	Reported mean	Estimated mean	Reported median	Estimated median	R^2	Root mean squared error
EV/EBITDA	15.54	15.34	12.98	12.61	0.97	2.27
Price/book	2.37	2.28	1.65	1.59	0.87	0.90
Price/sales	3.35	3.21	2.52	2.32	0.85	1.43

estimate of fair the value of these investments.

Finally, we present two case studies of individual equity transactions and what the EDHEC*infra* asset pricing model predicts. We show that the value of individual cases is well captured by a systematic, risk-based approach to asset valuation.

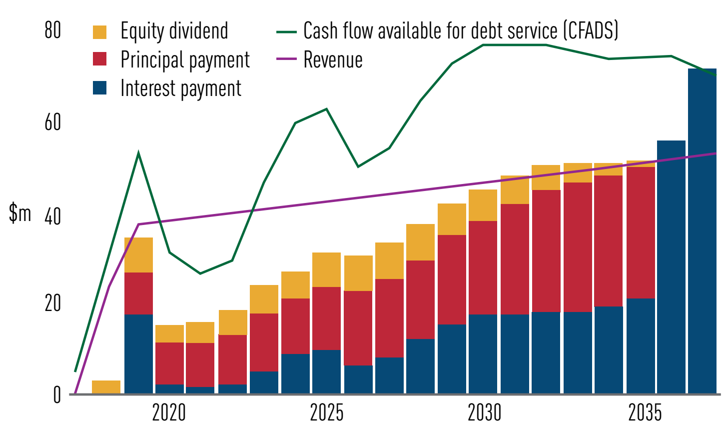
CASE STUDY: 2018 Cloosh Valley Wind Farm equity sale

A partially contracted onshore wind energy project in Ireland

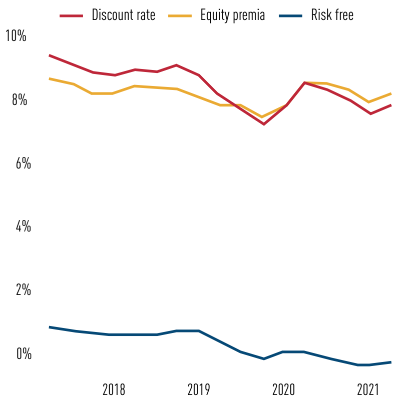
Cloosh Valley Wind Farm has a capacity of 108MW. The project is contracted under Ireland's REFIT 2 support regime until 2032, was financed in 2015 and became partly operational in 2018. In September 2018, developer Coillte sold 25% of the company to GR Wind Farms for €34.5m. Remaining project life at the time was 19 years, until 2037. Revenue growth forecast was 2% per year at the time.

Figure A shows the factor loadings for this company's equity premium model at the time of the transaction and the resulting valuation inputs. The investment factor (capex) is still high compared to the sector average because the

A. Factor loadings and valuation inputs



B. Valuation vs market price at valuation time



C. Risk factor loadings, risk premium and discount rates, Q3 2018

	Company	Sector*	Global*
Factor loadings			
Leverage	-99.7%	79.3%	78.1%
Size ($m)	220.9	350.8	1,326.9
Profitability	10.2%	15.1%	11.2%
Investment	38.6%	8.3%	4.3%
Term spread	1.8%	2.1%	2.0%
Valuation inputs			
Risk premia	8.4%	5.2%	5.8%
Discount rate	9.0%	6.9%	7.8%

** average on valuation date*

project is still partly at the development stage, which has the effect of increasing

D. Estimated vs reported valuations

	Reported	Estimated	% diff
Equity price ($m)	160.15	155.32	-3.01%
EV/EBITDA	19.65	19.37	-1.40%
Price/sales	7.74	7.50	-3.01%
Price/book	7.15	6.94	-3.01%

the risk premia, as does the lower than average profit factor loading.

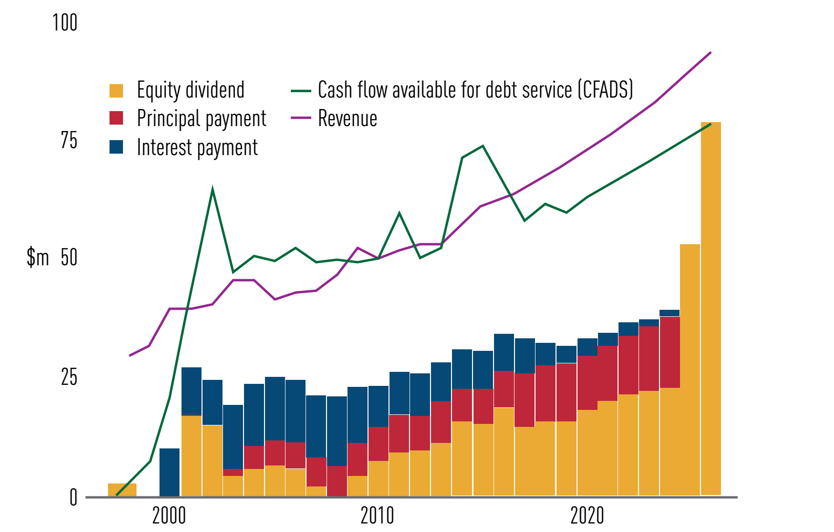
For these reasons, discount rates are higher than the sector average but later decrease reflecting the evolution of the risk profile. Figure B shows the model-predicted valuation versus the observed market price at the valuation time.

CASE STUDY: 2010 M40 motorway equity sale

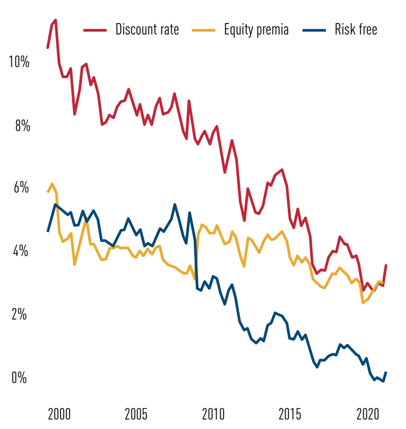
A DFBO road concession in the UK
The M40 motorway is 143km long, linking London, Oxford and Birmingham. It is constructed under the government's design-build-finance-operate (DBFO) scheme with a 30-year concession and payment is by traffic-related shadow tolls from the government over the life of the contract. In September 2010, John Laing Infrastructure Fund acquired a 50% controlling interest in UK Highways M40 Motorway for £37.1m (at a valuation of $115m). Remaining project life at the time was 16 years, until 2026. Average revenue growth forecast was 2.7% per year.

Figure A shows the factor loadings for this company's equity premium model at the time of the transaction and the

A. Factor loadings and valuation inputs



B. Valuation vs market price at valuation time



C. Risk factor loadings, risk premium and discount rates, Q3 2010

	Company	Sector*	Global*
Factor loadings			
Leverage	91.4%	83.7%	78.7%
Size ($m)	218.6	915.4	1,103.1
Profitability	6.1%	6.6%	10.3%
Investment	0.0%	8.7%	8.9%
Term spread	3.4%	3.7%	3.5%
Valuation inputs			
Risk premia	4.3%	6.3%	8.8%
Discount rate	7.0%	11.0%	12.4%

** average on valuation date*

D. Estimated vs reported valuations

	Reported	Estimated	% diff
Equity price ($m)	115.49	156.31	0.71%
EV/EBITDA	20.14	20.20	0.31%
Price/sales	2.64	2.66	0.71%
Price/book	3.13	3.15	0.71%

resulting valuation inputs. While leverage and profitability were in line with the sector's average, the company reported no capex (investment factor) at the time, leading to lower risk premia compared to the sector average. Figure B shows the model-predicted valuation compared with the observed market price at the valuation time.

The volatility of unlisted infrastructure investments

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This article summarises the findings of a new paper in which we examine the drivers of the volatility of unlisted infrastructure equity investments – that is, the reasons why the market prices of such investments can and do vary over time

The volatility of infrastructure equity investments is the risk that investors take to receive a reward for holding such assets. A robust measure of this risk and its drivers is an essential part of the inclusion of infrastructure investments in the portfolio, from strategic asset allocation to risk management and reporting, to manager compensation.

However, measuring this risk is difficult because the only available data is often limited to quarterly appraisals that do not reflect the current state of market prices but are instead 'stale' – ie, backwards-looking and leading to very 'smooth' returns, exhibiting highly unrealistic (low) levels of risk per unit of return. Appraisal-based indices typically report unrealistic total return volatility in the 2–3% range, leading to very high and unrealistic risk-adjusted returns (Sharpe ratio above 3).

Our analysis uses the EDHEC*infra* database of unlisted infrastructure equity investment data, which covers hundreds of firms over 20 years and a new approach to measuring the market value of these investments over time. Thanks to this technology, which predicts actual market prices very precisely, it is possible to measure the variability of unlisted infrastructure equity prices and to describe its fundamental components.

The market value of these investments is determined by the combination of expected cash flows (dividends), and a discount rate that combines a term structure of interest rates (the value of time) and a risk premium to compensate investors for the uncertainty of the future payouts. On average, the applicable

Appraisals are stale – a walk through the facts

Until recently, the only data available to assess the volatility of unlisted infrastructure investments was the reported net asset values (NAVs) resulting from regular appraisals of individual assets.

In the case of unlisted infrastructure equity, appraisals are typically produced using the 'income' or discounted cash flow approach, by which the value of the asset is:

$$P_j = \sum_{t=1}^{T} \frac{D_{j,t}}{\left(1+r_t+\gamma_j\right)^t}$$

where T is the investment's expected life, r_t is the risk-free rate at each point in time until date T and γ is the deal's risk premia.

In practice, r_t is typically set to be a moving average of long-term bond yields and γ is also a long-run average usually based on the capital asset pricing model (CAPM). While these estimates do vary over time, they are typically 'smooth' – ie, they do not reflect the current latest market conditions but rather tend to capture a trend. In fact, most private company appraisals aim to represent the value that a company is 'expected to be sold for' – ie, not current market conditions.

Moreover, using the CAPM requires estimating a single asset beta to derive the equity risk premia of a given investment. In the absence of listed proxies for most unlisted infrastructure assets, this estimate of the asset beta is often little more than an educated guess with little to no basis, and no scheme for revising it over time.

This approach also assumes that a single public equity risk premium is a fair representation of all the risks to which unlisted infrastructure assets are exposed. Academic research has long shown that this is not the case even for listed stocks, which are instead exposed to a number of risk factors in different ways.

Investors in unlisted assets are familiar with the issue of 'smoothed' returns – ie, reported performance that does not capture variability of market prices but instead relies on historical discount rates or minimal and lagged changes to the discount rate.

This reporting phenomenon results in the equally familiar 'stale' pricing issue: reported NAVs are not in line with market prices but instead reflect either a valuation at cost or one that has slowly drifted from its historical cost but is not, in the words of the IFRS 13 standard, calibrated using the latest market data.

Still, the most significant issue arising from smooth discount rates and stale NAVs is the underreporting of risk. We know from empirical research in finance that expected returns are better proxied by risk levels than by historical returns (Merton [1980]). If the risk level implied by the reported volatility of appraisals in these funds was true, infrastructure would represent a huge risk-free arbitrage opportunity with a Sharpe ratio of 3. In fact, if the reported volatility was true and fund managers were willing to sell these assets so cheaply on a risk-adjusted basis, they would be generating large negative alpha.

market discount rate is also a reflection of investors' expected return.

Using our approach to mark unlisted infrastructure to market, we find that the combination of changes in expected dividends (eg, following a change in demand for transport services or energy) and of changes in expected returns lead to a level of total return volatility in the 7–12% range. The resulting risk-adjusted returns are realistic while still attractive.

Looking at the components of the change in market value of unlisted infrastructure, we find that infrastructure equity risk can be driven at least as much by changes in expected cash flows as by changes in expected returns. This is an important and sometimes neglected aspect of the risk of investing in infrastructure: while cash flows are typically understood to be quite stable, the long life of infrastructure investments makes their value sensitive to changes in discount rates. Therefore, assessing the evolution of investors' expected returns in unlisted infrastructure equity is essential to arrive at a robust measure of risk at any point in time.

Key findings

We report the following stylised facts on the causes and trends of the volatility and market prices of unlisted infrastructure equity:

A shift in valuations after 2008
Our results confirm the oft-mentioned anecdotal evidence that unlisted infrastructure valuations have increased a lot since 2008–09. In fact, the realised volatility of unlisted infrastructure investments is in part the result of the development of the asset class and an increase in valuations which reflects a systemic increase in the level of demand for these assets and therefore a significant one-off shift in the price of unlisted infrastructure equity risk between 2009 and 2016. Before 2008, the average market expected returns for unlisted infrastructure equity were in the low double digits but decreased steadily after that to reach a trough of 6% towards the end of 2016.

'Peak infra' was in 2017
We also find that, after 2017, average expected returns reach a new 'steady state' between 7% and 8%. Thus, despite frequent claims that infrastructure assets are continuously getting more expensive, we confirm the previous empirical findings of Blanc-Brude and Tran (2019) that 'peak infra' (the highest average level of valuations) was reached in the 2016–17 period and that unlisted infrastructure valuations have been following a different path since then.

Expected returns spike during crises
Since 2020, the average level of expected returns has breached 8% for the first time since 2015. We note similar spikes during the 2008 financial crisis, 2012, eurozone debt crisis, Brexit, etc.

Duration is a good measure of forward-looking risk
A significant proportion of the realised volatility of unlisted infrastructure returns in the past 15 years is the result of this revaluation – ie, one-way capital gains that were created by a significant increase in the demand for such assets. Still, unlisted infrastructure remains volatile and exposed to the same risks, but realised volatility over the past two decades is perhaps not the best proxy of the asset class's forward-looking volatility.

We show that in the more recent period (past five years), the volatility of private infrastructure asset prices has been mostly driven by a combination of movements in interest rates and risk premia, the magnitude of which is much greater than changes in future dividends. It follows that the duration of unlisted infrastructure equity (its sensitivity to discount rate changes) is the most informative forward-looking measure of risk. We report significant levels of duration between 7.6% and 11.6% in Q1 2021, depending on TICCS® segments. Duration presents the advantage of combining the impact of changes in the risk premia (which is systematic but firm specific) with that of interest rates, which is country specific.

Systematic risk factors drive expected returns
We show that the risk premia of individual private infrastructure companies are driven by a combination of microeconomic and macro-economic factors, which are consistent with academic research and financial theory. These changes in the determinants of the price of equity risk are at the heart of the volatility of private infrastructure. In particular:

- The leverage factor premium, which is the largest contributor to the discount rate, has halved since 2010 but reversed its course in 2020. In line with financial theory, higher leverage commands a higher premium, even though this effect tails off rapidly on average for highly leveraged assets, which, by design, tend to be the safest infrastructure projects.
- The size factor premium exhibits more short-term volatility and reached a floor in 2015. This factor can be considered a proxy of the relative liquidity of infrastructure investments: ceteris paribus larger assets command a higher premium. This result sometimes seems to contradict the anecdotal evidence that large 'trophy' assets command higher prices (and therefore lower premia) in the market. However, this suggestion ignores the independence of factor premia. High prices for highly-demanded large assets are the result of the combined effect of all risk factors. Indeed, large sought-after infrastructure companies also tend to be highly profitable.
- The profit factor premium is the only negative contributor to aggregate risk premia: higher profits lead to lower risk premia (higher valuations). This factor premium has achieved a full rotation since 2000, reaching a peak in 2012 when higher profits barely achieved a higher valuation and returning to its 2000 level by 2020. This factor can be interpreted as a sign of greater risk aversion among buyers of unlisted infrastructure. In this sense, it reached its lowest level in 20 years just before the COVID-19 pandemic. Negative profits (leading to a higher premium) are also a contributor to the so-called 'greenfield' premium, which characterises early development projects.
- The investment factor premium exhibits the most stability over the past 20 decades. High investment (capex) in infrastructure companies is related to the life-cycle of the firm, including the greenfield phase during which sinking larger amounts of capex commands a higher premium. Investment also contributes to a greenfield premium.
- Country risk (term spread): a steeper yield curve indicates greater long-term uncertainty, which in the case of infrastructure can be associated with country risk and tends to increase the risk premia.
- A range of control variables, including business model and industrial activities according to the TICCS taxonomy of infrastructure companies, in particular their business model and corporate structure. For instance, when infrastructure companies collect risky revenues, either based on demand or traffic, they command a higher risk premium than when they do not (and are either contracted or regulated).

Thus, investments in unlisted infrastructure equity can be characterised as investing in a combination of exposures to a time-varying (infrastructure) equity risk premium, as well as a significant amount of interest rate risk. It is these effects that explain the non-negligible volatility of unlisted infrastructure equity investments, which is itself the reflection of investors risk preferences and perception

1. Total returns, risk and expected returns of the unlisted infrastructure asset class and selected TICCS segments; data as of Q1 2021

Indices	1-year total return	5-year total return	5-year volatility	10-year total return	10-year volatility	99.5% 1-year VaR	Maximum drawdown	Duration	Expected returns
infra300	−3.92%	4.08%	9.79%	13.46%	12.69%	21.21%	13.75%	8.69%	8.8%
Global infrastructure	−1.15%	6.42%	9.68%	14.64%	12.35%	18.97%	13.70%	8.03%	8.6%
Contracted	2.81%	6.62%	8.13%	14.79%	11.26%	14.98%	10.35%	7.67%	7.7%
Merchant	−3.37%	5.82%	11.77%	14.38%	14.63%	27.18%	21.60%	7.70%	10.6%
Global transport	−4.22%	6.16%	11.45%	15.17%	14.93%	26.90%	22.41%	8.56%	8.7%
Airports	−19.79%	−0.92%	16.22%	11.85%	17.78%	36.00%	34.89%	11.63%	8.9%
Global projects	0.97%	7.88%	9.07%	15.73%	12.03%	17.02%	13.93%	7.66%	8.2%
Global wind	−0.25%	7.86%	8.19%	15.22%	10.48%	11.37%	9.55%	7.40%	6.6%
Global core	0.96%	9.43%	7.33%	15.04%	10.36%	12.46%	11.16%	7.73%	6.2%
Global core+	−1.88%	10.95%	9.67%	17.94%	12.40%	14.62%	11.86%	9.19%	9.1%
Mid-market	−0.11%	11.13%	9.40%	16.88%	10.94%	12.07%	10.88%	7.70%	8.8%
Range in bp*	2,260	1,210	890	610	740	2,460	2,530	420	440

Source: EDHEC*infra*. * maximum – minimum value. As of Q1 2021, local currency returns. 99.5% one-year Cornish Fisher VaR. Expected returns as of Q1 2021. TICCS segments except for core and core+, represented by the first two and the third quantiles of expected returns, respectively, and mid-market, which is defined as the second and third size quantiles in the universe.

of the uncertainty with which expected dividends may be paid, including not at all (bankruptcy risk).

A granular range of risk profiles

Because risk factor exposures vary between different segments of the unlisted infrastructure market, a range of risk profiles exists, some of which are shown in figure 1, which shows that returns can be negative and variable, more so in certain segments that are exposed to market risk (eg, merchant infrastructure) and less so in contracted projects, which tend to have a lower duration and less risky cash flows, hence a lower but also less volatile risk premium. We also see that in the cross-section of TICCS segments the range of risk and return profiles is significant.

Convergence with public market prices for comparable assets

Pricing private infrastructure equity risk in public markets

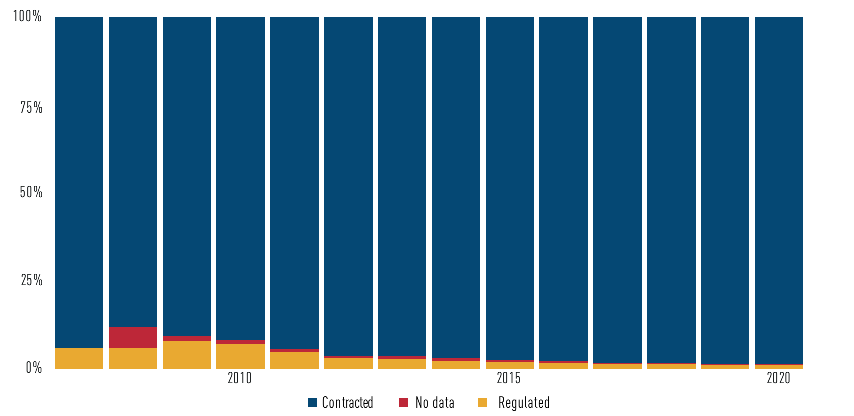
We provide an additional robustness test of these results by way of a natural experiment: we consider 14 listed funds that only invest in unlisted infrastructure equity with negligible additional fund-level leverage and a well-defined focus on UK social and renewable energy projects, which we can easily map to the TICCS classification of infrastructure assets and create a private proxy of these funds with the EDHEC*infra* index data.

Infrastructure fund data

At the end of 2020, the funds represented an aggregate market value of £18.5bn, reported appraisal value of £16.5bn and various ownership stakes in more than 800 individual unlisted infrastructure projects. These unlisted equity investments are primarily UK-based, social and renewable energy infrastructure projects as shown in figures 2–6.

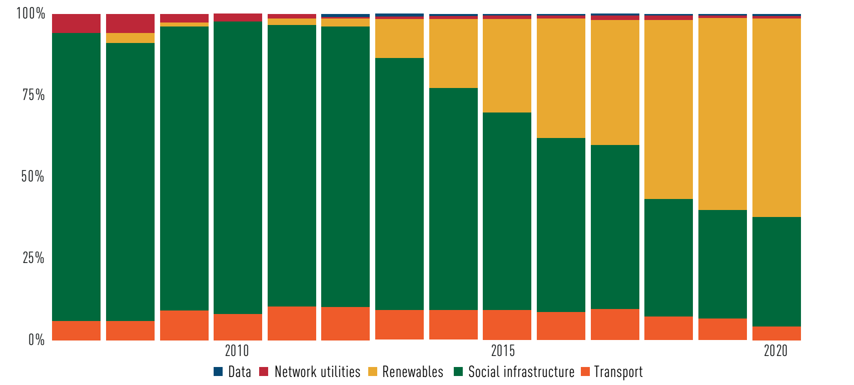
With a few exceptions, these invest-

2. TICCS segmentation of the unlisted infrastructure investments of 15 public infrastructure funds by business model



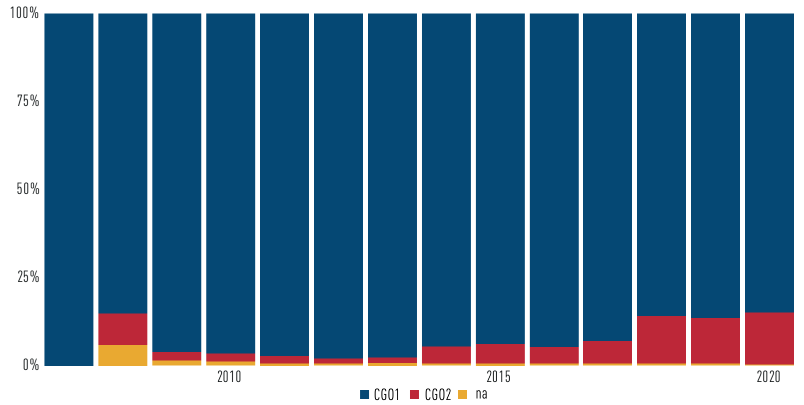
Source: annual and quarterly reports, EDHEC*infra*

3. TICCS segmentation of the unlisted infrastructure investments of 15 public infrastructure funds by industrial activity



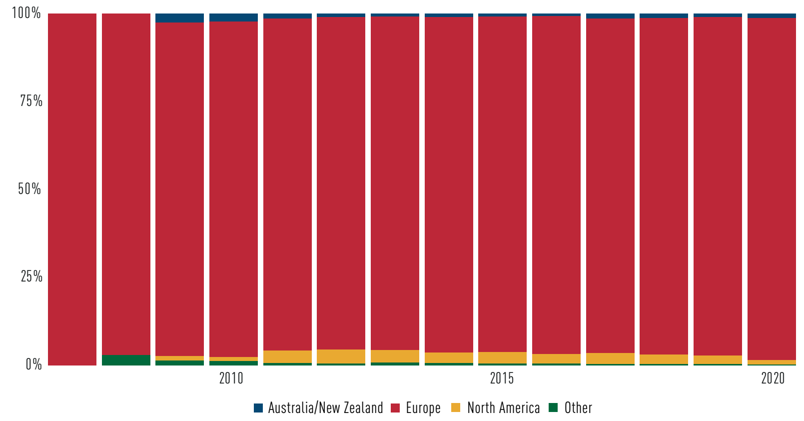
Source: annual and quarterly reports, EDHEC*infra*

4. TICCS segmentation of the unlisted infrastructure investments of 15 public infrastructure funds by corporate structure



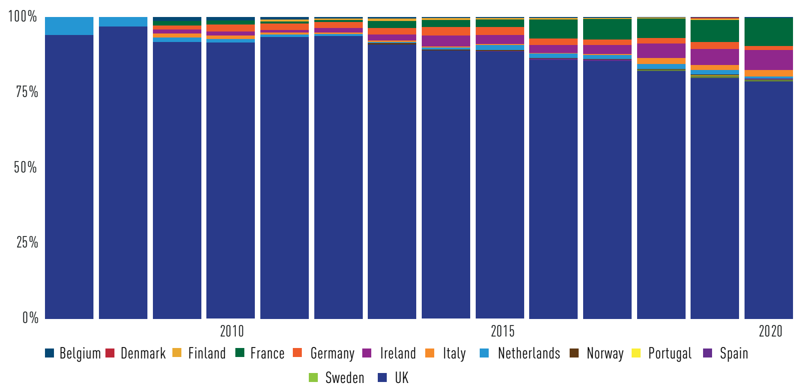
Source: annual and quarterly reports, EDHEC*infra*

5. TICCS segmentation of the unlisted infrastructure investments of 15 public infrastructure funds by region



Source: annual and quarterly reports, EDHEC*infra*

6. TICCS segmentation of the unlisted infrastructure investments of 15 public infrastructure funds by European country



Source: annual and quarterly reports, EDHEC*infra*

ments and the funds themselves can be grouped into two themes as shown in figure 3: investors in public-private partnership projects (PPPs) in social infrastructure (TICCS–IC 30) and investors in renewable energy projects, especially wind (TICCS–IC 7010) and solar power (TICCS–IC 720). Figures 2–6 also show the breakdown of the underlying investments made by these funds in other segments of the universe, using a detailed dataset listing each one of their investments in every year since they were created. In aggregate, the TICCS allocation of this group of funds changes over time but remains highly focused on contracted (TICCS–BR 10, figure 2) projects (TICCS–CG 10, figure 4) located in Europe, primarily in the UK (figure 6). Figure 7 also shows that the shares of the sample by number of underlying assets, by market capitalisation and by appraisal net asset value are such that, while some funds are much larger than others, no individual fund or theme dominates this sample. We also report leverage at the fund level in figure 8, which shows the quantiles of the leverage reported by the funds in their annual reports over the entire period. Fund leverage is minimal and typically transitory – ie, these funds tend not to have much debt. Thus, these funds represent a genuine listed proxy of direct holdings of several hundred unlisted infrastructure project equity investments in the social and renewable energy sectors in the UK.

Private market equivalent
To compare this basket to a similar portfolio of unlisted assets, we build a custom portfolio using the data from the EDHEC*infra* universe, designed to have exactly the same TICCS and geographic weights as the listed one, following the weights shows in figure 9 at each point in time. It consists of 141 wholly-owned underlying assets in 2020 and represents £16bn of market value at the end of 2020. All assets in this index are priced on a quarterly basis using the methodology described in the previous chapter. Next, we compute market-implied discount rates for these funds and compare them with appraisal discount rates and private market discount rates for the same investments.

Market-implied discount rate
As argued above, the main issue with the discount rates used in the appraisal of unlisted infrastructure equity investments is their lack of market-testing or calibration to market inputs. We illustrate this point by computing the market-implied discount rates of the public infrastructure funds described above.

Since these publicly quoted vehicles solely hold the equity of unlisted infrastructure assets, we can use their public prices in combination with their reported unlisted asset appraisal discount rates to derive a market-implied equivalent of their discount rates using the market

7. Public infrastructure funds investing in unlisted social and renewable energy infrastructure project equity, share of total by number of underlying assets

Fund	Code	ISIN	Investment theme	Number of assets	By market value	By appraisal value
International Public Partnership	INPP	GB00B188SR50	PPP	11.36%	13.85%	13.32%
Greencoat UK Wind	UKW	GB00B8SC6K54	Renewables	3.14%	12.91%	13.39%
Gore Street Energy Storage Fund	GSF	GB00BG0P0V73	Renewables	0.45%	0.79%	0.78%
HICL Infrastructure	HICL	GB00BJLP1Y77	PPP	17.19%	16.24%	16.33%
Aquila European Renewables Income Fund Plc	AERI	GB00BK6RLF66	Renewables	0.90%	1.48%	1.58%
John Laing Infrastructure Fund	JLIF	GG00B4ZWPH08	PPP	9.57%	5.96%	7.05%
Bluefield Solar Income Fund	BSIF	GG00BB0RDB98	Renewables	7.62%	2.70%	2.64%
The Renewables Infrastructure Group	TRIG	GG00BBHX2H91	Renewables	11.51%	13.00%	13.14%
Nextenergy Solar Fund	NESF	GG00BJ0JVY01	Renewables	13.45%	2.97%	3.27%
JLEN Environmental Assets Group	JLEN	GG00BJL5FH87	Renewables	3.74%	3.11%	2.90%
GCP Infrastructure Investments Limited	GCP	JE00B6173J15	PPP	4.04%	4.60%	5.09%
Foresight Solar Fund	FSFL	JE00BD3QJR55	Renewables	8.37%	3.15%	3.22%
3i Infrastructure	3IN	JE00BF5FX167	PPP	2.99%	13.43%	12.32%
Balfour Beatty Global Infra	BBGI	LU0686550053	PPP	5.68%	5.82%	4.98%
Total as of YE 2020				**784**	**£18.5bn**	**£16.5bn**

Source: London Stock Exchange, annual reports, Datastream, EDHEC*infra*

9. Average impact on market NAV of change in rates, future dividends and market risk premia on different segments of the unlisted infrastructure equity universe; data as of Q1 2021

Average change in NAV	... due to change in dividend forecast	... due to change in the term structure of rates	... due to change in equity risk premia
Global infrastructure			
1-yr change	–4.0%	–1.2%	–3.9%
3-yr change	–2.0%	7.4%	–8.2%
5-yr change	2.1%	9.9%	–9.4%
Contracted			
1-yr change	–0.2%	–1.0%	–2.7%
3-yr change	–0.3%	7.3%	–5.6%
5-yr change	3.6%	9.9%	–7.0%
Merchant			
1-yr change	-7.20%	-1.30%	–6.90%
3-yr change	-5.20%	7.20%	–12.50%
5-yr change	-2.20%	8.50%	–13.20%
Global transport			
1-yr change	–6.10%	–0.50%	–5.60%
3-yr change	–6.70%	8.80%	–11.70%
5-yr change	–0.40%	11.00%	–11.70%
Airport			
1-yr change	–4.40%	–5.20%	–13.70%
3-yr change	–8.30%	10.20%	–26.40%
5-yr change	12.40%	13.80%	–27.20%
Global projects			
1-yr change	–2.90%	–0.50%	–3.00%
3-yr change	–1.70%	7.40%	–7.00%
5-yr change	2.80%	9.70%	–8.00%
Global core			
1-yr change	–2.60%	0.00%	–2.20%
3-yr change	–0.50%	7.20%	–5.10%
5-yr change	2.70%	9.40%	–6.00%
Global core+			
1-yr change	–4.70%	–1.60%	–4.40%
3-yr change	0.10%	8.10%	–9.10%
5-yr change	8.80%	9.40%	–9.60%

Source: EDHEC*infra*

8. Quantiles of leverage in public infrastructure funds, 2010–20

Quantile	0%	25%	50%	75%	100%
Median	0%	0%	0%	1%	2%
Mean	0%	4%	6%	10%	13%

premium to their NAVs. Indeed, the actual (market-implied) discount rate of these funds' unlisted assets can be written as a function of its actual market yield and a factor adjusting for the difference.

For simplicity, assume a Gordon dividend growth model to represent asset values. We have:

$$P_t = \frac{D}{y_t - g}$$

and

$$NAV_t = \frac{D}{r_t - g}$$

With P_t the market price of an asset, D the dividend payout, y the market expected rate of return or yield and g the perpetual dividend growth rate. NAV_t is the appraisal NAV and r the appraisal discount rate. It follows that the ratio of the market price to the appraisal NAV is:

$$\frac{P_t}{NAV_t} = \frac{D}{y_t - g} / \frac{D}{r_t - g}$$
$$= r_t / y_t$$

And the market-implied yield can be written as a function of the appraisal discount rate, reported NAV and the market price of the asset.

$$y_t = r_t / \frac{P_t}{NAV_t}$$
$$= r_t / (1 + \delta_t)$$

with δ_t the NAV premium of the asset. That is, when an asset trades above its NAV (at a premium), its market discount rate or yield is equal to its appraisal NAV discount rate adjusted by a factor equal to $1/(1 + \delta_t)$ with $\delta > 0$ – ie, a lower effective discount rate than its appraisal discount rate.

Figures 10 and 11 show the average NAV premium (10) and the average market-implied discount rate (11) for the 14 funds. We find that these funds have been trading at a premium to their NAV at least since 2010, with a premium ranging between 5% and 15%. Their average market-implied discount rates have been trending down from 8–9% in 2010 to 6–7% in 2020, following the familiar yield compression trend already discussed in the previous section.

Next, we compare the average market-implied discount rate of these funds with their appraisal discount rate and that of the private market custom index. Figures 10–12 show that the average difference between market-implied discount rates and appraisals is constant over time: appraisals do decline over time but they never catch up with the level of discount implied by market prices.

Conversely, private market discount rates (duration-adjusted) represented by the EDHEC*infra* custom index, show a clear convergence with their listed equivalent: between 2010 and 2015, private assets were relatively cheap compared with the public price and commanded a significantly higher discount rate. This is, again, a familiar picture of the higher return/discount rates of unlisted infrastructure before 2016, as discussed earlier.

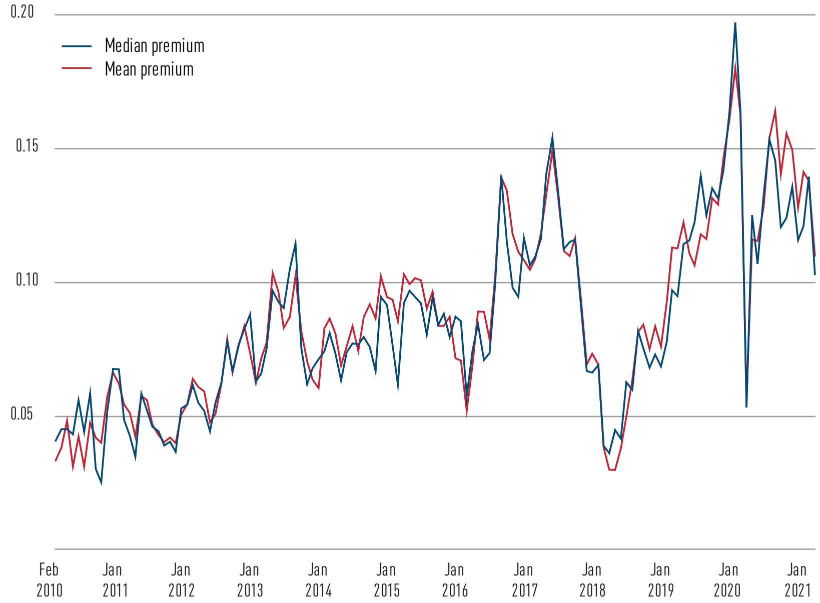
As the private market yield is driven down by the high demand for these assets, it overshoots the public market-implied yield between 2016 and 2018, by which time, unlisted infrastructure PPPs and renewable investments are effectively more expensive (have a lower yield) than their publicly listed equivalent. From 2018 onwards however, they have converged and become very close. Figure 12 shows that the difference between the public market-implied and private-market discount rates decreases steadily over time and is less than 10bp at the end of the period – not significantly different from zero. There is no such convergence with appraisal discount rates which maintain 80–90bp average difference with market-implied rates, confirming that they are not market-tested.

Convergence

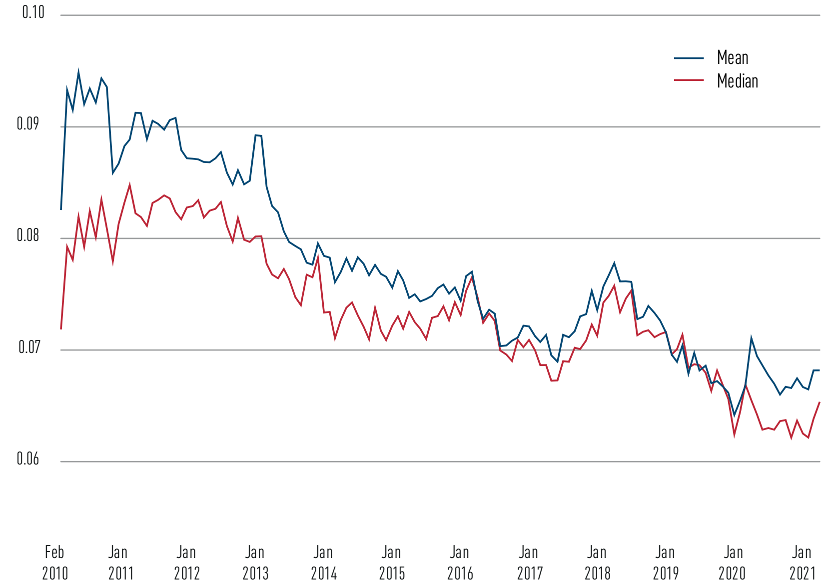
Thus, two comparable sets of underlying investments exposed to similar risk factors, one listed and one not, are found to exhibit similar levels of expected returns and risk pricing after 2018, following a decade long period of convergence. This finding confirms both that unlisted infrastructure went through a period of repricing prior to 2016 which led to significant capital gains but also more variability of prices – ie, volatility of returns – and that from 2017 onwards, infrastructure valuations have entered into a more stable state, in line with the price of risk found in capital markets. This result provides a powerful robustness check of the risk factor model described in the previous section and the historical decline and stabilisation of the price of risk it documents empirically.

To summarise: we use the reported appraisal NAV, appraisal discount rates and

10. Average quarterly NAV premium of public infrastructure funds investing in social infrastructure and renewable energy in the UK, Q1 2010–Q1 2021



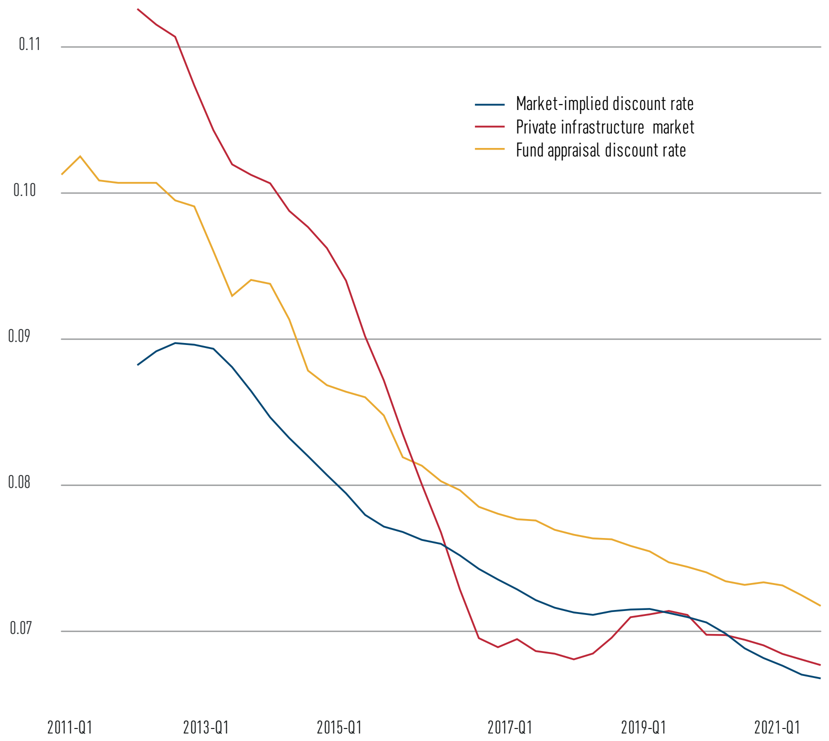
11. Average quarterly market-implied discount rates of public infrastructure funds investing in social infrastructure and renewable energy in the UK, Q1 2010–Q1 2021



12. Average reported discount rates vs market-implied discount rates of PPP and renewable energy infrastructure funds

Period	Market-implied discount rate	Appraisals		Private infrastructure market	
		Discount rate	Difference with market	Discount rate	Difference with market
2010–14	8.28%	9.11%	0.83%	9.91%	1.63%
2015–18	7.26%	7.88%	0.62%	7.00%	–0.25%
2019–20	6.70%	7.61%	0.91%	6.80%	0.10%

13. Rolling average of appraisal discount rates and market-implied discount rates for comparable baskets of UK renewable and social infrastructure projects



traded price of these funds to show that their market-implied expected returns (discount rate adjusted for the NAV premium) have been converging with the expected returns of the equivalent segment of unlisted infrastructure equity. This finding confirms that unlisted infrastructure used to trade at a significant (price) discount to comparable listed assets but that this gap narrowed quickly as the asset class became more in demand and even overshot public market expected returns between 2016 and 2018. Since 2018, we find that expected returns have converged for two listed and unlisted baskets of the same UK renewable energy and social infrastructure projects (see figure 13).

Conclusion

We conclude that a robust measure of the volatility of unlisted infrastructure equity is possible because it relies on an equally robust asset valuation technology. This highlights the importance of taking duration into account when investing in infrastructure to anticipate changes in the market values of unlisted infrastructure equity. For a given stream of cash flows, a large part of this risk is driven by a country-specific (or macro) component (the yield curve) and a firm-specific (but systematic) component which is the combination of the risk factor exposures and the market price of these same risks.

Despite the a priori view that infrastructure is low risk, and the myopic perception of very low return volatility created by appraisals, infrastructure equity investments are risky and exhibit a non-negligible level of volatility, albeit an attractive risk-adjusted return profile.

These findings are essential for the good management and monitoring of unlisted infrastructure. With adequate and believable measures of volatility, infrastructure can be addressed from a total portfolio perspective (strategic allocation), from a prudential perspective (eg, Solvency-II) using methods that apply across asset classes.

In fine, the understanding and documentation of the volatility of unlisted infrastructure condition its development as a fully-fledged asset class.

References

Blanc-Brude, F., and C. Tran (2019). What factors explain unlisted infrastructure asset prices? EDHEC Infrastructure Institute Publication, available at https://edhec.infrastructure.institute/paper/which-factors-explain-unlisted-infrastructure-asset-prices/

Merton, R. (1980). On estimating the expected return on the market: An exploratory investigation. Capital Markets: Asset Pricing & Valuation. NBER Working Paper No. w0444, available at SSRN: https://ssrn.com/abstract=262067

The next generation of data for infrastructure investors

Frédéric Blanc-Brude, Director, EDHEC*infra*

A new generation of research and data finally enables the industry to gauge the fair value and risk of this asset class, something that has been lacking for many years

Alongside building the largest database of infrastructure investment data in the world, EDHEC*infra* has also been busy creating a state-of-the-art 'index and analytics data platform' for investors to access not only its several hundred indices but also valuation metrics, discount rate tools and soon a fund analyser tool that promises to revolutionise the way fund GPs and LPs can benchmark funds.

1. Index and analytics data produced by EDHECinfra

Market indices		*Available quarterly and monthly*	
Including		infra300® infraGreen® infraDebt500®	
Sub-indices and benchmarks		*Available quarterly*	
Global TICCS® indices	Equity style indices	Debt style indices	Geographies
	(core, core+, mid-market ...)	(Investment grade, RPI-linked, fixed/floating rate ...)	(Regions and selected countries)
Risk and performance analytics		*Available quarterly and monthly for selected indices*	
Capital gains	Cash yield	TICCS contributions	Maximum drawdown
Value-at-risk	Duration	Expected loss	Default risk
Valuation metrics		*Available quarterly and monthly*	
Market ratios	Risk premia	DCF drivers	Cost of capital
Credit spreads	Yield to maturity		
Fund benchmarking tool		*Updated quarterly*	*Available Q3 2021*
by style	by vintage	by horizon	by fee structure
PMEs	Direct alpha	Dietz returns	IRR quartiles
Peer-group benchmarking		*Updated semi-annually*	*Available Q3 2021*
Peer group ratings	Peer group performance	Peer group style analysis	

Source: edhecinfra.com

The next generation

The infrastructure asset class has long suffered from a lack of adequate measures of fair value and risk. A new generation of research and data on unlisted infrastructure equity and debt allows asset owners and managers, consultants and regulators to access the true characteristics of the asset class.

Thanks to years of research, data collection and industry collaboration, EDHEC*infra* produces a series of essential tools and datasets that support the growth of the asset class by making it more transparent and well understood. This includes:

- Key market indices tracking the fair market value of a representative set of hundreds of investments in unlisted infrastructure equity and debt produced on a quarterly and monthly basis. Hundreds of sub-indices provide access to granular benchmarks using the TICCS® taxonomy of infrastructure companies, across geographies or investment styles.
- For each segment of the unlisted equity and debt universe, essential risk analytics are also available, including extreme risk and credit risk measures.
- Valuation metrics reflecting the latest evolution of the market price of risk for different types and styles of infrastructure and a dynamic valuation tool for investors to estimate the risk premia of their own assets using the latest information from secondary market data.
- A fund benchmarking tool uses mark-to-market returns for hundreds of unlisted equity infrastructure investments over the past 20 years to simulate thousands of funds invested in specific strategies or segments and produce robust benchmarks of fund performance (available in Q2 2021).
- Peer group benchmarking using pooled portfolios of actual holdings by investors, comparing the strategies, risk and alpha of direct investors, asset managers etc. Peer groups are based on in-depth research on individual portfolio holdings by asset owners and managers on an ongoing basis and the fair market valuation of the relevant assets.

EDHEC*infra* is also at the origin of a classification system of infrastructure investments (TICCS) as well as data collection standards for the evaluation and reporting of performance at the asset level. These standards are validated and used across the industry to create transparent and robust assessments of the performance and risks of the asset class. Users of EDHEC*infra* data include the largest asset managers and asset owners in the world, prominent consultants and valuers, as well as prudential and economic regulators.

The infrastructure investment toolkit

We maintain the largest database of infrastructure investments in the world:

- 6,800-plus unlisted companies identified;
- 650-plus equity investments tracked;
- 1,200-plus private debt instruments tracked;
- 20 years of data.

EDHEC*infra* has identified more than 6,800 private investible infrastructure companies in 25 countries, from which it has built a representative set of 650-plus tracked investments and 1,200-plus financial debt instruments going back 20 years. Investors in infrastructure have access to the analytics needed to evaluate, benchmark, compare investments in unlisted infrastructure equity and debt using 20 years of data collected and curated by the EDHEC*infra* team.

Equity metrics are available by TICCS segment including business risk, industry and corporate structure, as well as equity styles including core, core-plus, mid-market, etc. Debt metrics are also available by TICCS segment and by debt investment styles including investment grade, fixed rate, floating rate and inflation-linked (UK only).

The science of accurate valuations

Measuring the market price of illiquid, unlisted infrastructure investments is not straightforward due to the paucity of available data. However, recent advances in data collection and asset pricing using robust, scientific methods and now give very good results.

As more investors consider allocations to unlisted infrastructure, the need to bring the asset class into the mainstream of risk management, asset allocation and prudential regulation is increasing rapidly. Reflecting the impact of COVID-19 on infrastructure valuations has made this trend all the more urgent. Appraisal values typically imply very smooth returns that do not reflect the latest market conditions. In the absence of comparable transactions, most unlisted infrastructure investments have effectively been booked at or near historical cost. However, thanks to recent advances in data collection and asset pricing techniques, it is now possible to estimate the evolution of fair market prices for unlisted infrastructure equity investments. It can be shown that:

- Common risk factors explain observable valuations of unlisted infrastructure companies.
- The risk premia of these factors can be measured on an ongoing basis, as new transactions take place. Thanks to these risk premia, individual assets that do not trade but are exposed to the same factors can also be priced.
- This approach predicts transaction prices accurately within 5% of observed transaction prices and produces robust series of returns with no smoothing.

This technology allows the measurement of the true yield of infrastructure investments, their optimal contribution to multi-asset portfolios, duration and much more.

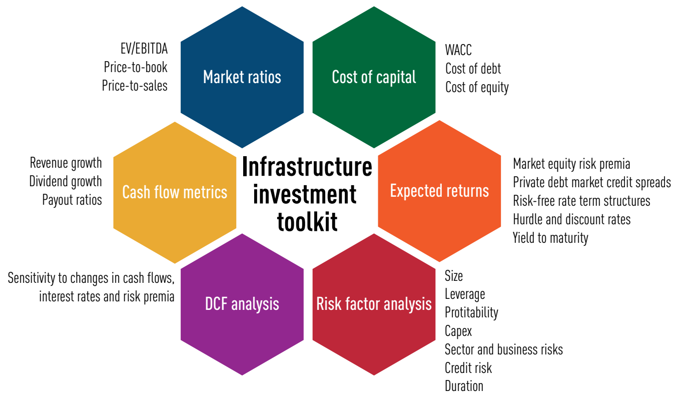
For example, looking at a comparison between model-predicted ratios like EV/EBIDTA, price-to-book and price-to-sales against actual deal values for a large and diversified set of observed transactions between 2000 and 2020 (see figure 3), we see in figure 4 that model-predicted prices are accurate. The prediction error is typically within 5% or less of observed prices.

While we cannot use 'comps', because there are too few observable prices, we can reduce the number of dimensions of the problem to a few systematic risk factors that are found in every transaction. On each valuation date, the fair value of any infrastructure investment is a function of: a) a future stream of dividends, b) the term structure of risk-free rates in that country and at the relevant horizon and c) a risk premium.

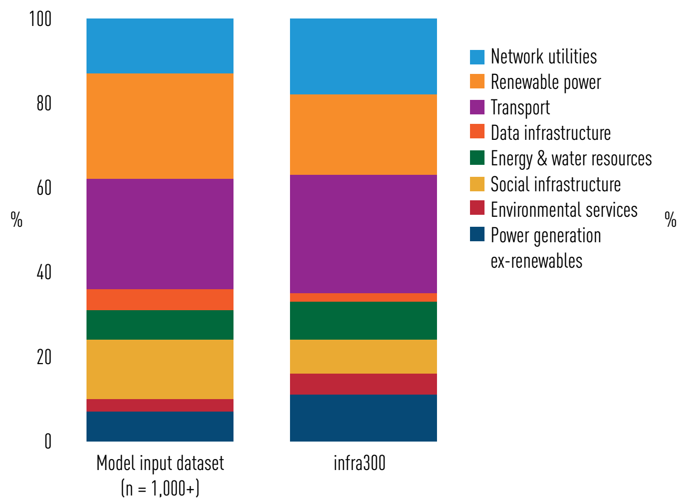
Given a stream of expected cash flows (which can come from the asset owner), and a term structure of rates (built using the yield of risk-free bonds at the relevant horizons, in the relevant country), estimating the fair value of unlisted infrastructure equity boils down to estimating the equity risk premium for a given company.

EDHEC*infra* research has determined

2. The infrastructure investment toolkit



3. Transaction price data used in valuations vs infra300 index



4. Estimated vs reported valuation ratios and model goodness of fit

Ratio	Reported mean	Estimated mean	Reported median	Estimated median	R^2	Root mean squared error
EV/EBITDA	15.54	15.34	12.98	12.61	0.97	2.27
Price/book	2.37	2.28	1.65	1.59	0.87	0.90
Price/sales	3.35	3.21	2.52	2.32	0.85	1.43

that the most relevant, robust and persistent risk factors that explain transaction prices in unlisted infrastructure transactions are:

- Leverage (liabilities/total assets);
- Size (total assets);
- Profitability (return on assets pre-tax)
- Investment (capex/total assets);
- Country risk (term spread).
- A range of control variables including business model and industrial activities, according to the TICCS taxonomy.

These factors are in line with fundamental concepts in asset pricing and corporate finance. For example, higher leverage should increase the cost of equity as per the Modigliani and Miller theorem, and the size, profits and investment are well established risk factors in modern equity valuation since Fama and French. With this technology and curated datasets, it is possible to measure the fair value of unlisted investments on a fair market basis on an ongoing basis and to provide investors and regulators with the granular and accurate information they need.

What is infrastructure investment really like?

Frédéric Blanc-Brude, Director, EDHEC*infra*

Using the EDHEC*infra* data, valuation approach and the TICCS® classification gives investors the true view on what investing in infrastructure is really like

Monitoring exposure

Being exposed to 'infrastructure' can often be a little abstract. In effect, investors are exposed to some infrastructure. Using granular data and an objective classification system confirms that the difference in risk-adjusted performance between different segments of the infrastructure universe is significant, and suggests that investors need to monitor their exposure to infrastructure in detail, as shown by figure 1.

The period of COVID-19 in particular has highlighted how differently exposed to certain risks investors in infrastructure can be. The COVID pandemic revealed both the capacity for resilience of certain types of infrastructure like contacted projects and the exposure to economic risks of merchant corporates, two segments well captured by the TICCS taxonomy.

The EDHEC*infra* approach also reveals the sources of the risk and performance of the different segments of the asset class. Beyond the impact of cash flows, their relative exposure to interest rate risk and changes in risk premia of these companies are major components of the ongoing fair value of unlisted infrastructure companies. In effect, changes in the fair value discount rates are much more significant drivers of risk and performance than changes in future cash flows, even in a period like the COVID pandemic.

For example, using EDHEC*infra* data for a sample of 500-plus unlisted infrastructure equity investments in 22 countries in 2020, lower future dividends due to COVID-19 contributed on average to reducing the net asset value of unlisted infrastructure investments by approximately –3.5%, while downward movements in interest rates contributed to increasing valuations by more than +5%. Higher risk market premia further deflated them by as much as –9%. Over the past three years, for the same universe, the cumulative impact of changes in interest rates on fair values is +15%, compared to less than 1% for changes in expected cash flows.

But the most appealing feature of unlisted infrastructure equity investment remains its cash yield, which is the main source of stability and attractiveness in risk-adjusted terms. Recent research by EDHEC*infra* shows that infrastructure

1. Performance and risk measures of key segments of the infrastructure equity and debt universe

As of Q4 2020, local currency

Indices	1-year total return*	3-year total return	5-year total return	10-year total return	10-year volatility	99.5% 1-year value-at -risk	Maximum drawdown	Modifed duration**
infra300	–1.9%	3.2%	6.6%	13.8%	12.6%	25.2%	31.3%	9.30
Contracted infrastructure	2.0%	6.7%	8.4%	15.0%	11.2%	19.9%	27.6%	7.90
Merchant infrastructure	–6.6%	4.7%	9.8%	15.3%	14.3%	29.1%	35.5%	10.20
Roads	6.0%	9.7%	11.5%	16.1%	15.3%	31.7%	31.2%	11.10
Airports	–35.1%	–12.6%	–0.7%	10.5%	18.3%	40.7%	39.8%	13.50
Global projects	2.1%	8.4%	10.3%	16.3%	11.9%	21.9%	29.4%	8.50
Global corporates	–13.5%	–2.5%	3.0%	11.2%	13.9%	29.8%	34.0%	9.60

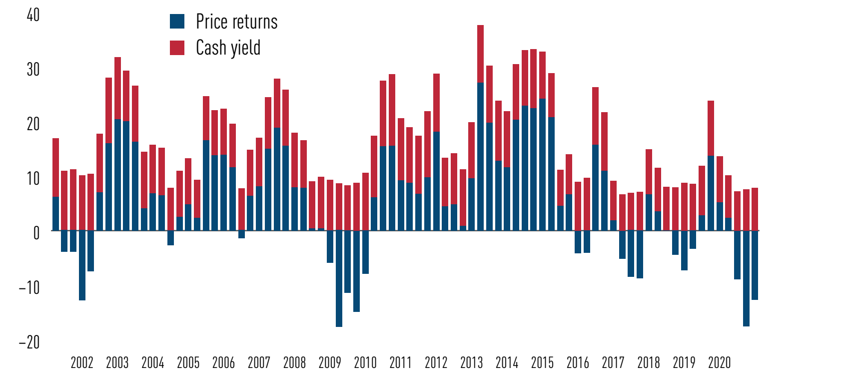
*estimated at YE 2020; **percentage change in value for one percentage change in discount rate

Source: indices.edhecinfra.com

companies are very good at paying dividends compared to other firms (Whittaker and Tan [2020]). Thus, the cash yield of the infra300 index remains at 7% to 8% in recent years, as shown in figure 2.

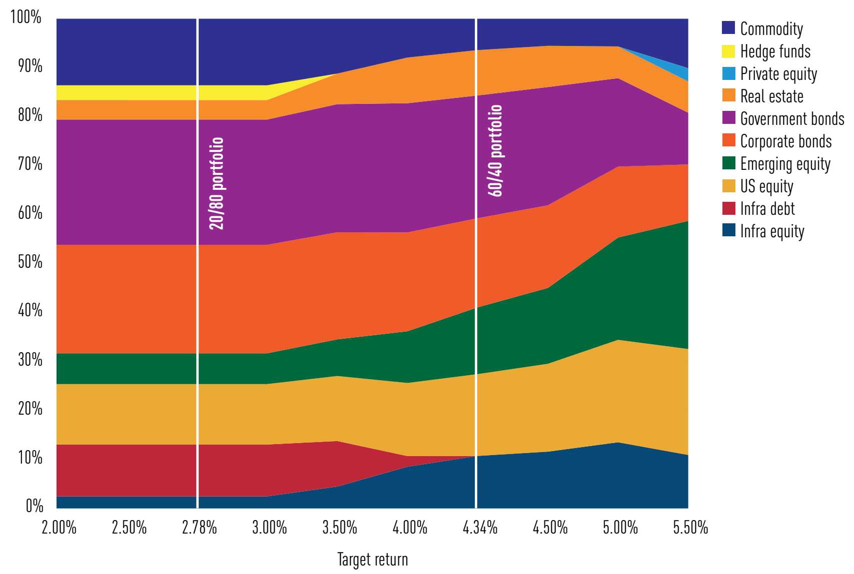
Measuring the true volatility of unlisted infrastructure investments presents the significant advantage of allowing investors to engage in asset and risk management. Figure 3 shows that in a multi-asset context with 10 asset classes, unlisted infrastructure equity and debt always have a role to play in the portfolios of different styles of investors and, moreover, that optimal allocations could be as high as 10% compared with the much lower current levels. Once the performance of the asset class is adequately measured on a fair value basis, investing in unlisted infrastructure can bring significant advantages to investors: it is a demonstrable source of diversification, income and liability hedging – just as long as it is properly benchmarked within the portfolio.

2. Year-on-year price and cash flow returns of the infra300 index (unlisted equity)



Source: indices.edhecinfra.com

3. Optimal asset allocations with 10 asset classes including unlisted infrastructure and debt



Source: Amenc et al (2021). Strategic Asset Allocation to Unlisted Infrastructure. EDHEC Infrastrcture Institute Publications. Forward-looking return and risk data EDHECinfra; other asset classes based on market consensus.

TICCS: define your style

Collecting a lot of infrastructure data required EDHEC*infra* to create a taxonomy of infrastructure investments: The Infrastructure Company Classification Standard (TICCS) was first released in October 2018 and soon became an industry standard that allows the definition of clear and robust investment styles in the asset class.

There are several ways to define 'infrastructure': the OECD and the World Bank use definitions that focus on what infrastructure does – that is, delivering essential services. For the purposes of classifying investments in infrastructure, a better approach focuses on what infrastructure 'is like' in terms of its attributes as a business. This is the route taken by financial regulators in their effort to define qualifying infrastructure assets under various prudential frameworks. Criteria-based definitions of qualifying infrastructure companies exist under the Basel-II Accord, the Solvency-II Directive and the CRR-2 Regulation of European banks.

The TICCS view

TICCS is not strictly speaking a definition of what is and what is not 'infrastructure' but a taxonomy to objectively organise the constituents of the infrastructure investment universe. We identify six fundamental economic criteria for an asset to be meaningfully designated as 'infrastructure':

● Single-use investment: infrastructure assets are 'relationship-specific' – ie, the investment required only makes sense in the context of a 'relationship': typically a contract, licence or concession.

● Sunk or irreversible capital investment: this relationship is needed because the initial capital expenditure is 'sunk' – ie, irreversibly invested and unusable for any other purpose than the one originally intended.

● Large size requiring a long repayment period: the investment is sizeable in absolute terms, making the repayment period necessarily long.

● Inflexible total cost structure: infrastructure assets have highly predictable fixed costs and low variable costs, resulting in an inflexible cost structure. Hence the need for certainty of future revenue streams and the role of long-term contracts since assets have no alternative use.

● Infrastructure as a service: infrastructure companies have value because their assets provide a useful service to users, despite consisting mainly of large tangible, immobile assets.

● Not a store of value: unlike other 'real' assets such as land, buildings, etc, infrastructure is not a store of value, only a provider of useful services.

An industry standard

On this basis, TICCS has four pillars, as shown in figure 4. The super-class level (eg, transport), breaks down into class-level sectors (eg, rail) and asset level subclasses (eg, high-speed rail). TICCS is the subject of annual market consultations and reviewed by the independent TICCS Review Committee (see box).

TICCS is used by pension funds, insurers and asset managers to categorise their investments and reflect their exposures to well-defined segments of the infrastructure universe that can also be benchmarked by equivalent sub-indices since the EDHEC*infra* data is organised using the same taxonomy. For example, an investor in contracted and merchant infrastructure projects – across social and transport infrastructure – can design a representative portfolio benchmark using the weights of each segments in its own portfolio.

From academic insights to industry relevance

Robust research practices and the objective to create solutions for the industry are at the heart of the EDHEC*infra* approach. EDHEC*infra* was created in 2015 at EDHEC Business School thanks to the support of the Monetary Authority of Singapore, Natixis, Meridiam, Campbell Lutyens, the members of the Long-Term Infrastructure Investors Association and the Global Infrastructure Hub (a G20 initiative).

From the onset, the objective of EDHEC*infra* was the creation of industrial-grade market indices and benchmarks for the purpose of documenting the characteristics of the infrastructure asset class. The academic DNA of EDHEC*infra* means that we put modern financial theory first. In practice, it means that returns must correspond to risks priced by markets and that asset valuations should reflect current market data, especially the latest changes in interest rates and risk premia.

We set out to build a representative, bias-free database of investible infrastructure companies including data on both equity and debt instruments, and to design asset pricing models that could capture the evolution of the price of risk for unlisted infrastructure investments.

The industry supports this effort and the EDHEC*infra* Advisory Board provided essential guidance as EDHEC*infra* developed its approach and designed the benchmarks and valuation tools the industry and regulators need.

In September 2015, in a letter to the dean of EDHEC, the chairman of EIOPA wrote that the conclusions of the regulator, with regard to the definition and treatment of infrastructure under Solvency-II, 'draw to a very large extent on the work of Professor Blanc-Brude' (EIOPA 15-726). Since then, numerous investors have started using EDHEC*infra* indices and benchmarks directly in the investment process, including for risk reporting, asset allocation and performance monitoring. EDHEC*infra* now provides the industry with its only access to current, mark-to-market, representative indices and benchmarks of the risk-adjusted performance of unlisted infrastructure equity and debt.

Thanks to this project, the infrastructure asset class has entered a new era of transparency and granular data, which will continue to improve the prudential treatment of the asset class, increase global asset allocations to unlisted infrastructure and support the development of the infrastructure investment industry.

4. The four TICCS pillars

Pillar 1: Business risk	Pillar II: Industrial activity	Pillar III: Geo-economic exposure	Pillar IV: Corporate governance
Contracted	Power ex-renewables	Global	Regional
Merchant	Environmental services	Regional	Corporates
Regulated	Social infrastructure	National	
	Energy and water resources	Subnationa	
	Data infrastructure		
	Transport		
	Renewable power		
	Network utilities		

TICCS

– three classes and five sub-classes of business risk;

– eight industrial super-classes, corresponding to 33 industry classes of specific industrial activities and 95 industrial asset-level subclasses;

– four geo-economic classifications; and

– two corporate governance classes with two subclasses.

TICCS Review Committee

As of Q1 2021

- **Andrew Knight** (RICS) – Chairman
- **Avi Turetsky** (Landmark Partners) – Secretary
- **Mark Blair** (OTTP)
- **Anne-Christine Champion** (Natixis)
- **James Davis** (OPTrust)
- **Christophe Dossarp** (SOURCE)
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- **Marie Lam-Frendo** (Global Infrastructure Hub – G20)
- **Serge Lauper** (BlackRock)
- **Trevor Lewis** (Asian Development Bank)
- **Christoph Manser** (Swiss Life)
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- **Petya Nikolova** (New York City Comptroller's Office)
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EDHEC*infra* Advisory Board

Members include:

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- **Ian Berry** (River & Mercantile)
- **John Faye** (CDPQ)
- **Sancho Chan** (Sunlife)

Reference

Whittaker, T., and R. Tan (2020). Anatomy of a Cash Cow, An In-Depth Look at the Financial Characteristics of Infrastructure Companies, EDHECinfra white paper, July.

Towards a scientific approach to ESG for infrastructure investors

Approaching ESG and infrastructure within the portfolio

Nishtha Manocha, Senior Research Engineer, EDHEC*infra*;
Frédéric Blanc-Brude, Director, EDHEC*infra*

This article summarises a new paper exploring the role of environmental, social and governance (ESG) issues in an investment context[1]

How should institutional investors incorporate ESG elements into the financial management of their portfolios? A growing number are pursuing ESG objectives, a choice that will inevitably have a financial impact on portfolio performance. It is this area that we investigate here – the role of ESG within an infrastructure portfolio from a strictly financial standpoint. Thus we address the following question: how should we gauge the relationship between ESG and the market value of infrastructure investments?

This is a key question that institutional investors and prudential regulators need answered in order to integrate ESG into their financial decision-making process – eg, to assess sustainability risks under the Sustainable Finance Disclosure Regulation (SFDR) of the European Union. Existing ESG reporting and assessment schemes are not designed to answer this question, but can provide a basis for a robust scientific framework that would create genuine ESG investment knowledge.

ESG reporting and investors' demand for monitoring

Beyond the affirmation and realisation of such non-financial objectives, ESG reporting and assessment schemes on infrastructure assets have also developed in a financial context. This is a response to an increasing demand for monitoring from investors who need more information than can be gleaned from the market price of assets to make investment decisions.

Indeed, while the primary fiduciary responsibility of institutional investors such as pension plans or life insurers is to help their plan members meet their long-term investment and consumption objectives in real terms, they may also decide to pursue any number of non-financial objectives. Figure 1 shows examples of how ESG-related non-financial objectives such as promoting gender equality exist alongside aspects of ESG that are directly related to the pursuit of financial objectives.

1. ESG-related objectives and ESG aspects of financial objectives

ESG-related non-financial objectives	ESG aspects of financial objectives
Promote environmental sustainability	Manage climate change-related physical risks
Support energy transition	Manage climate transition risks
Promote human development	Minimise environmental and social reputation risk
Promote gender equality	Minimise reporting and compliance risks

Investors in infrastructure have two sets of decisions to make relating to ESG:
- First, which assets should they exclude or focus on because of their ESG characteristics?
- Second, given the characteristics of the acceptable universe, what risks are they exposed to that they should manage within their portfolio, through various forms of diversification, hedging or insurance?

If the impact of ESG characteristics on infrastructure asset prices is not easily gauged from market prices, then additional investment knowledge is needed to decide how to invest. Thus, beyond the societal demand for greater ESG content and outcomes of the investments made by investors, the demand for ESG reporting and benchmarking also springs from the second motive described above, as does the need to manage risks related to ESG within the portfolio. In the end, the relationship between ESG and the fair market value of assets is determined by the extent to which the ESG profile of a firm creates exposures to risks that materially (systematically) drive the discount rates of the future cash flows of its financial assets.

This focus on risk may seem at odds with the frequent insistence on the role of the 'impact' of a business or project in the 'green investing' literature or marketing. Of course, any economic activity has an impact and infrastructure companies can have very significant impacts, both positive and negative, on their natural and economic environments. However, these impacts do, in turn, create risks – ie, they increase or decrease the payoff uncertainty of the investment. In fine, impacts contribute to the discount rate or expected return that investors require to buy or hold the asset.

1 Blanc-Brude & Manocha (2021).

Existing ESG reporting frameworks do not create investment knowledge

Next, we ask if existing ESG reporting tools create the investment knowledge that investors require – ie, do ESG schemes created and used by infrastructure investors help clarify the relationship between ESG and infrastructure asset prices? Over the past decade, in response to the increasing appetite of investors for understanding and measuring the ESG characteristics of infrastructure investments, numerous tools and standards have appeared to facilitate the reporting and assessment of ESG metrics. ESG schemes for infrastructure investors are still at the 'proliferation' stage of standard development and a degree of consolidation, as well as integration of these soft rules into more stringent and mandatory regulatory frameworks can be expected.

We propose a framework to integrate the role of ESG in the fundamental relationship between risk and fair value, which takes into account the role of each infrastructure company's impacts on environmental, social and governance matters. To develop this framework, we conduct a comparative analysis of the existing ESG schemes used by infrastructure investors to determine the scope of ESG issues in relation to infrastructure investments, establish a common matrix or taxonomy of their ESG risks and impacts, and determine how the question of (financial) materiality – ie, what factors can be expected to systematically impact value, should be approached scientifically.

From the multiple standards available, we build a parsimonious taxonomy of ESG impacts and risks that, at the most general level, universally apply to any infrastructure company.

We use this taxonomy, which includes 10 super-classes, 24 classes and 67

Scope

Measuring infrastructure ESG performance requires clear definitions of both infrastructure and ESG performance.

However, looking at the scopes of each scheme and framework and whether they diverge significantly, we find that, in line with Berg et al (2019), the aim, creators, intended end-users and, crucially, the definition of 'infrastructure' used all vary sufficiently between schemes and frameworks to suggest significant scope divergence.

These schemes and frameworks define the infrastructure sector with varying granularity. As shown in figure A, although standard-setters like GRESB and an increasingly large number of investors use The Infrastructure Company Classification Standard (TICCS®), other schemes use in-house stand-alone definitions of infrastructure, with different degrees of overlap, including with TICCS. Other multi-sector schemes use industry filters such as GICS®, which do not isolate infrastructure companies from equipment suppliers and other types of firms active in an industry. It is important to point out that the definition of infrastructure used aligns with the aims of the schemes and their primary user types. For example, investor-related schemes may benefit from aligning with TICCS, while other schemes looking to identify and assess impact and risks from an engineering standpoint may use in-house classifications.

Schemes and guiding frameworks that are designed specifically for the infrastructure sector or cover the infrastructure sector in some detail include the SuRe standard, SASB, GRESB infrastructure asset assessment, CEEQUAL, the Envision rating tool, PPIAF and the IS Rating Scheme. Others are not sector-specific and include infrastructure together with other sectors and thus do not capture the infrastructure very well.

A. Infrastructure classification system followed and target sectors of ESG schemes

Scheme	Infrastructure classification system followed	Target sectors
SuRe	No classification available; it is applicable to all types of infrastructure projects	Including but not limited to: water, energy, solid waste, transport networks, nodes and fleet, communication networks, social infrastructure, food systems, mining and extractive sites
SASB	In-house classification: SICS (Sustainable Industry Classification System)	Infrastructure standards include: electric utilities and power generators, gas utilities and distributors, water utilities and services, waste management, engineering and construction services, home builders, real estate, real estate services
GRI Standards	Not applicable	Not infrastructure-specific
GRESB infrastructure asset assessment	TICCS® (The Infrastructure Company Classification Standard)	Data infrastructure, energy and water resources, environmental services, network utilities, power generation (excluding renewables), renewable power, social infrastructure and transport
MSCI ESG Ratings	Not applicable for ESG ratings, but infrastructure indices use GICS® (Global Industry Classification Standard)	Not infrastructure-specific
IS Rating Scheme (Australia and NZ)	In-house classification	Including but not limited to: airports, rails, roads, social infrastructure, ports, telecommunication, utilities, waste, water
RepRisk Index and Ratings	Not applicable	Not infrastructure-specific
Refinitiv ESG Scores	In-house classification: Thomson Reuters Business Classification (TRBC)	Not infrastructure-specific
EU Taxonomy	Recommendations structured around EU's NACE (Nomenclature des Activités Économiques dans la Communauté Européenne) industry classification system	Not infrastructure-specific
CEEQUAL (International)	No classification available; it is applicable to all types of infrastructure projects	Any infrastructure project that involves the construction of new assets or refurbishment of existing assets
Envision rating tool	In-house classification	Energy, water, waste, transportation, landscape, information
Sustainability and Resilience SmartScan	No classification available; it is applicable to all types of infrastructure projects	Including but not limited to: water, energy, solid waste, transport networks, nodes and fleet, communication networks, social infrastructure, food systems, mining and extractive sectors
PRI	Not applicable	Not infrastructure-specific; however, infrastructure-specific reporting framework is available, which is applicable to all infrastructure investments
Equator Principles	Not applicable	Not infrastructure-specific
IFC Environmental and Social Performance Standards	In-house classification	Not infrastructure-specific
PPIAF	In-house classification	ICT, transport, water and sanitation, power
SDGs	Not applicable	Not infrastructure-specific

subclasses of ESG impacts and risks, to categorise 1,659 indicators, including 4,850 disclosures provided by existing schemes. This allows us to understand the scope, level of aggregation, and measurement difference of existing ESG schemes for infrastructure investment.

We find that despite current ESG standards being made for the purpose of infrastructure investing, the centrality of the firm and the importance of asset pricing are often ignored by or lost on existing schemes. These typically do not achieve a clear distinction between impacts and risks, in particular between those impacts and risks that ESG reporting and assessment should focus on. Instead, they tend to be lists of 'things that matter' and do not necessarily focus on trying to measure the risks to which investors in infrastructure companies are exposed in the context of ESG. We argue that such lists, while very useful, fail to meet the standard of a genuine scientific framework: a list of concepts and categories that describe the relationships between them – ie, an ontology.

To define infrastructure, we follow the TICCS classification system of infrastructure companies, which puts the firm at the centre of the approach. Infrastructure companies are what equity investors buy and debt investors lend to. Hence our focus is the ESG impacts of an infrastructure company, and what ESG risks it is exposed to. It follows that any ESG reporting or scoring, while it may spring from asset-level data, can be evaluated at the firm level, which is the correct unit of account for an investment reporting scheme.

There is little convergence between schemes in terms of scope (what the ESG perimeter includes), weights (what defines or constitutes materiality) and measurement (what data should be used to capture ESG characteristics). From one scheme to the next, the ESG performance of infrastructure companies is currently measured and presented in different and evolving ways. We find:

- Significant scope divergence between schemes as evidenced by the different biases, incomplete coverage and lack of overlap in terms of risk and impact classes, which is also a sign of measurement divergence;
- Measurement bias in the reporting of ESG information with the dominance of qualitative measures reported;
- Impact bias in the reporting of ESG information, and little attention to measuring risk exposures, especially not through quantitative risk reporting;
- Process and input indicator bias in the reporting of ESG information, highlighting the role of proxies in the various scoring and ratings methodologies used since actual impacts are not directly measured or reported.

Because of their lack of focus on the firm and its value, existing schemes focus almost entirely on 'impacts', which may of course be indirect factors of risk, but also do not shed much light on the direct risks that arise from ESG. Some 88% of reviewed disclosures focus on impacts while only 12% aim to capture direct risks. Our findings point to several likely developments in the area of ESG ratings and certification provision:

- Infrastructure investment ESG standards will continue to change: the current absence of consistent definitions or approaches means that individual standards need to evolve and redefine their scope and methodologies;
- This consolidation will be driven by end users: the degree of clarity and consensus around the objectives and the definitions used by ESG schemes, as well as the embedded assumptions that underpin these choices are likely to contribute to standard adoption, credibility and, eventually, dominance;
- Schemes that also address the most pressing questions of policy makers and regulators are more likely to attract users. In the case of infrastructure investment, this is particularly the case with regard to climate change.

Creating an infrastructure ESG domain of knowledge for investors

To support the development of relevant ESG investment knowledge, we explicitly restrict the analytical framework to the link between ESG and asset prices.

Investors recognise that 'externalities have consequences' and, with rapid social and environmental changes over the past decades and the expectation of even more uncertain evolutions, they also anticipate these consequences by demanding better knowledge about their investment choices. This is what they and regulators need to understand in order to manage risks in the portfolio.

In the end, creating ESG investment knowledge does not change or remove economic externalities, it only makes them and their potential consequences for businesses more apparent and better documented. It is the knowledge of the uncertain consequences of externalities, including on future regulation or cash flows, that can influence asset prices.

In essence, the current demand for ESG reporting stems from two issues:

- A lack of knowledge regarding the ESG impacts and risks of infrastructure companies; and
- The fundamental uncertainty that the ESG aspects of their activity create for investors.

Addressing the first issue amounts to documenting the exposure (or beta) of a company to certain risks. For the second, the consequences of ESG impacts and risks themselves for the firm remain uncertain, but can inform decision making and become a driver of the cost of capital in infrastructure investment.

The scientific development of a body of ESG investment knowledge (or ontology) requires a number of key building blocks:

- The clearly stated aim to create knowledge that relates the ESG characteristics of infrastructure companies – the entities in which investors decide to buy or hold – to investment decisions made on financial grounds – ie, considerations of risk and reward.
- This helps clarify that the impacts of interest are those of an infrastructure company and the relevant risks are those to which the same company is exposed. Hence, the relevant domain of knowledge: instances of ESG risks and impacts of infrastructure companies. By grounding the approach in this manner, it becomes clearer that impacts are also sources of risks.
- Next, a classification system is needed for the various objects of interest, including of course infrastructure companies and their ESG risks and impacts, but also standard classes of attributes and relations that allow the ESG characteristics of infrastructure companies to be described and create this knowledge. The definition of the attributes and relations that create this knowledge can then be science- and theory-based, using the most consistent assumptions or models in order to create a broad user base and maximise potential commitment by users.
- Finally, this allows the question of materiality to be addressed. Materiality is a weak point in existing ESG schemes: they provide lists of potential material information to report or collect, but do not anchor this materiality in objective measures that would relate to the activities of infrastructure companies. Developing science-based materiality profiles for each of the 95 types of infrastructure assets captured in the industrial activity pillar of the TICCS classification is a key step in the development of a body of ESG investment knowledge for infrastructure investment.

Example: the environmental pillar

Following the TICCS approach, infrastructure companies invest in large, irreversible, immobile capital assets that have little to no alternative use. Given their significant physical footprint, they typically impact important areas of land and require substantial amounts of materials and natural resources to build, operate and maintain, refurbish and decommission. Throughout their life-cycle, infrastructure assets thus impact all aspects of stock of natural capital, from biodiversity (EI 1.1), to water (EI 1.2), land (EI 1.3) and the atmosphere (EI 1.4), including the climate (EI 1.4.2).

Indeed, as the backbone of modern economic activity, the ultimate role of infrastructure is often to support the consumption of energy by economic agents engaged in activities that require considerable amounts of energy, the vast majority of which is currently sourced from fossil fuel. Hence, most infrastructure contributes to a degree to greenhouse gas emissions. The definitions of each class and the relevant references are provided in the appendix to the full paper (Blanc-Brude & Manocha [2021]).

Infrastructure assets are also exposed to multiple environmental risks: their rigid and static nature implies that extreme weather events can damage physical assets or make them unusable if they become isolated from the the network within which they are designed to function. Earthquakes, landslides, etc. are good examples of physical risks that infrastructure asset can be exposed to (see Below et al [2009]; also see the appendix of our full paper for a complete list of risk classes). One of the consequences of climate change is indeed to increase the frequency and severity extreme weather events (Hoegh-Guldberg et al [2018]), making the likelihood and impact of such events sufficiently dynamic and difficult to predict today to challenge the technical and physical assumptions used when existing infrastructure assets were built. Likewise, the long-term consequences of climate change such as permanent shifts in temperature or sea levels create physical risks for infrastructure assets.

Environmental degradation may also lead to limiting or preventing an infrastructure from functioning normally if certain natural resources became unavailable (eg, water used as coolant in a power station, ER 2.2.2).

Thus, physical risk and access to resources are the super-classes of environmental risk to which infrastructure companies are exposed. Depending on their location, design and activities – ie, their attributes – infrastructure companies are more or less exposed to these risks.

Taken together, classes of environmental impacts and risks make up the environmental pillar of the taxonomy and figures 2 and 3 list the risk and impact classes of the environmental pillar.

2. Environmental pillar impact classes

Identifier	Class name	Class definition
EI 1	**Natural resources**	The world's stock of naturally occurring assets (including geology, soil, air, water and all living things) that can be used for economic production or consumption.
EI 1.1	**Biodiversity**	The variety and variability of life on Earth at the genetic, species, and ecosystem level.
EI 1.1.1	Loss	The decline in number, genetic variability, variety of species, and the biological communities in a given area.
EI 1.1.2	Disturbance	A temporary and localised change in environmental conditions that causes a pronounced change in an ecosystem.
EI 1.1.3	Restoration	The process of assisting in the recovery of habitats and establishing the ecological processes necessary to make terrestrial and aquatic ecosystems sustainable, resilient, and healthy under current and future conditions.
EI 1.1.4	Conservation	The practice of protecting and preserving the wealth and variety of the biodiversity and maintaining the function of the natural ecosystems of a given region.
EI 1.1.5	Enhancement	The process of improving the organisms and habitats of a given region.
EI 1.2	**Water resources**	Natural sources of water that that are useful for human activities.
EI 1.2.1	Pollution	Discharge of harmful substances or contaminants that cause degradation of the water quality of a given resource.
EI 1.2.2	Depletion	The consumption of a water resource faster than it can be replenished.
EI 1.2.3	Diversion	Mass movement of water of water temporarily or permanently.
EI 1.2.4	Preservation and protection	Protecting the quality, quantity and integrity of water resources.
EI 1.2.5	Restoration	The process of restoring the quality, quantity and integrity of the water bodies that have been subject to pollution or depletion.
EI 1.3	**Land**	Land resources refers to the soil geographic land (soil) and all the naturally occurring resources such as rocks, minerals and ores present under the surface of the land.
EI 1.3.1	Pollution	The deposition of waste materials on land or underground in a manner that can contaminate the soil.
EI 1.3.2	Change in land use	Human induced transforming of the landscape of a piece of land.
EI 1.3.3	Degradation	Decrease in the quality or integrity of soil that causes the economic or biological productivity of a given piece of land to fall.
EI 1.3.4	Preservation and protection	Protect the quality, quantity and integrity of land resources.
EI 1.3.5	Restoration	The process of restoring the quality, quantity and integrity of land resources that have been subject to pollution or degradation.
EI 1.4	**Atmosphere**	The blanket of gases that surrounds the earth.
EI 1.4.1	Air pollution	Release of gaseous and particulate contaminants into the air.
EI 1.4.2	Climate change	The abnormal variations and the significant long-term change in the expected patterns of the average weather of the Earth's local, regional and global climates.
EI 1.4.3	Air quality improvement	Reducing the concentration of contaminants present in the air.

3. Environmental pillar risk classes

Identifier	Class name	Class definition
ER 1	**Physical risk**	The risks that infrastructure assets face from physical events or natural disasters.
ER 1.1	**Geophysical events**	Events originating from solid earth.
ER 1.1.1	Earthquake risk	The physical risk stemming from the shaking and displacement of the ground due to seismic waves.
ER 1.1.2	Volcanic risk	The physical risk stemming from volcanic activity such as rock falls, ash falls, lava streams, gases etc.
ER 1.1.3	Mass movement (dry) risk	The physical risk stemming from the displacement caused by the physical movement of the earth.
ER 1.2	**Hydrological events**	Events associated with water occurrence, movement and distribution.
ER 1.2.1	Flood risk	The physical risk stemming from a significant rise in water levels.
ER 1.2.2	Mass movement (wet) risk	The physical risk stemming from the displacement caused by the physical movement of the earth caused by a change in hydrological conditions.
ER 1.3	**Climatological events**	Events caused by long-lived/meso to macro scale processes (in the spectrum of intra-seasonal or multi-decadal climatic variability).
ER 1.3.1	Extreme temperature risk	The physical risk stemming from a variation in temperature above or below normal conditions.
ER 1.3.2	Drought risk	The physical risk stemming from a long-term event triggered by a lack of precipitation.
ER 1.3.3	Wildfire risk	The physical risk stemming from an uncontrolled burning fire, usually in wild lands.
ER 1.4	**Meteorological events**	Events caused by long-lived/meso to macro scale atmospheric processes (in the spectrum of minutes or days).
ER 1.4.1	Storm risk	The physical risk stemming from the disturbance of the atmosphere marked by wind and one or more of rain, snow, hail, sleet or thunder and lightning.
ER 2	**Access to natural resources**	Access to natural resources can be understood as the opportunity and the ability to make use of the natural resources required for the activities of the infrastructure company.
ER 2.1	**Resource loss risk**	The risks associated with the reduction in the quantity or deterioration of quality of natural resources in a given geographic region.
ER 2.1.1	Quality risk	The deterioration of quality of natural resources in a given geographic region, associated with the human activities.
ER 2.1.2	Availability risk	The depletion in the stock of a natural resource in a given geographic region, associated with the human activities.

Example: relations between risks and impacts

We also consider how the impacts and risks classes are related. As discussed above this ontology includes relations between types and subtypes of risk and impacts. Based on desk research and expert opinion, a relation of the type was established between subclasses of impacts and/or risk.

Looking at the concentration of links between types of impacts and risks, we find that risk types are more often driven by types of impacts and identified almost three times more links between impacts and risks than between risk types.

We also find that:

- Environmental risk types dependthe most on types of environmental impacts, followed by governance impact types. They are independent of all types of risks.
- Social risks are driven by all types of impacts, as well as types of social and governance risks. Social risks are seemingly independent from the environmental risks faced by the firm.
- Governance risks are driven more by types of governance impacts and to a lesser extent by types of governance risks and some social risks.

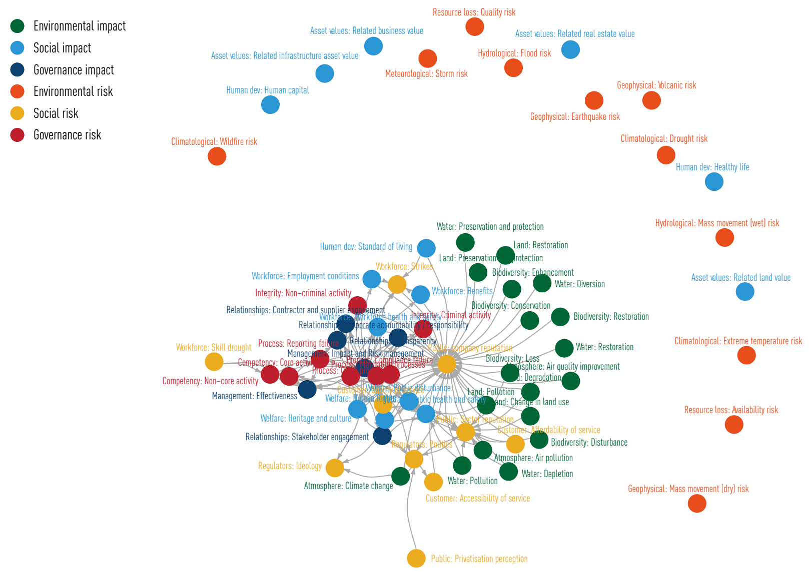
Impacts on the other hand tend to be related to other impact types but less often to types of risks.

The classes that are the most frequently related to other types are: governance impact types (GR 1.1.2: Impact and risk management and GI 1.2.3: Stakeholder engagement), an environmental impact type (EI 1.4.2: Climate change) and governance risk types (organisational failure risks of GR 1.2.2: absence of mandatory processed GR 1.2.1: other processes and GR 1.1.2 compliance failure).

Figures 4 and 5 provide an illustration of the links between classes. Figure 4 shows that impacts are mostly related with other impacts. Conversely, ESG impacts are also important drivers of ESG risks as shown in figure 5.

4. ESG impact classes relations

5. ESG risk classes relations



Alignment with SFDR

Our approach is aligned with the work of the EU's SFDR, which is expected to come fully into force in 2022. SFDR requires 'financial market participants and financial advisers (...) to disclose specific information regarding their approaches to the integration of sustainability risks and the consideration of adverse sustainability impacts' (SFDR, L317/2).

While its primary public policy objective is to minimise adverse impacts on the environment and society, as mentioned above, SFDR is also about the risks to asset values. It requires the disclosure of so-called sustainability risks that pose 'an environmental, social or governance event or condition that, if it occurs, could cause an actual or a potential material negative impact on the value of the investment' (SFDR, L317/9).

In effect, a taxonomy of the ESG impacts and risks of infrastructure companies is an essential step to address the concerns of SFDR. Moreover, one of the foundations of SFDR, is another taxonomy: the EU Taxonomy for Sustainable Activities describes the sustainability characteristics of various forms of industrial activities, including that of infrastructure companies. In other words, the EU taxonomy is a first attempt at building objective materiality profiles that can be used to assess the ESG characteristics of an infrastructure company objectively.

Finally, this description of what matters from an ESG standpoint is to be documented using Regulatory Technical

Standards (RTS) establishing a framework of reporting on principal adverse impacts and risks. A first draft describing the ESG data that will be required by the RTS was published in the Final Report on draft Regulatory Technical Standards, of the joint committee of the European Supervisory Authorities in February 2021, and describes detailed indicators for environmental and social impacts.

To ensure compatibility with the SFDR, the EDHEC*infra* ESG taxonomy allows mapping of the required disclosures to respective impact and risk classes. Given that the EDHEC*infra* taxonomy is an exhaustive list of ESG impacts and risks for the infrastructure sector, 100% of the mandatory disclosures can be mapped to the subclasses of this taxonomy of risks and impacts. To enable measurement, each impact and risk can then be measured as indicators, which in turn will be informed by data collected according to the materiality profiles of each company and asset type as defined by TICCS. In the RTS, these indicators are divided into a core set of 18 universal mandatory indicators that will always lead to principal adverse impacts of investment decisions on sustainability factors, irrespective of the result of the assessment by the financial market participant, and additional opt-in indicators for environmental and social factors, to be used to identify, assess and prioritise additional principal adverse impacts.

Future work by EDHEC*infra* focuses on supporting the implementation of the roadmap described in this paper, including documenting the ESG characteristics of infrastructure companies.

References

Below, R., A. Wirtz and D. Guha-Sapir (2009). Disaster category classification and peril terminology for operational purposes. Technical report.

Berg, F., J. F. Koelbel and R. Rigobon (2019). Aggregate confusion: The divergence of ESG ratings. Available at SSRN: https://ssrn.com/abstract=3438533

Blanc-Brude, F., and N. Manocha (2021). Towards a Scientific Approach to ESG for Infrastructure Investors. EDHEC*infra* white paper, March.

Hoegh-Guldberg, O., D. Jacob, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K. Ebi, F. Engelbrecht, J. Guiot et al (2018). Impacts of 1.5°C global warming on natural and human systems. Global warming of 1.5°C. An IPCC Special Report.

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