

A Publication of the EDHEC Infrastructure Institute–Singapore

Which Factors Explain Unlisted Infrastructure Asset Prices?

Evidence from 15 years of secondary market transaction data

January 2019



with the support of



Long-term
Infrastructure
Investors
Association



Table of Contents

Executive Summary	4
1 Introduction	10
2 Literature: Risk Factors and Infrastructure Returns	13
3 Approach & Data	21
4 Dynamic Modeling	28
5 Factor Estimation	34
6 Market Trends	46
7 Conclusion	66
References	75
About The Long-Term Infrastructure Investors Association	76
About EDHEC Infrastructure Institute-Singapore	78
EDHEC Infrastructure Institute Publications	82

About the Authors



Frédéric Blanc-Brude is the Director of EDHEC Infrastructure Institute. He holds a PhD in Finance (King's College London) and degrees from the London School of Economics, the Sorbonne, and Sciences Po Paris. He is a member of the editorial board of the *Journal of Alternative Investments*, a regular contributor to G20 and WEF working groups on long-term infrastructure investment, and has advised the European Insurance and Occupational Pensions Authority (EIOPA) on the prudential treatment of infrastructure investments. He also represents EDHEC on the Advisory Board of the Global Infrastructure Facility of the World Bank.



Christy Tran is a Senior Data Analyst at EDHEC Infrastructure Institute in Singapore. She holds a Bachelor of Business (Banking and Finance) from Nanyang Technological University and passed Level II of the CFA Program.

Executive Summary



Executive Summary

Unlisted infrastructure prices have increased considerably over the past decade. Was it a bubble or a normal phenomenon?

In this paper, we show that systematic risk factors can largely explain the evolution of average prices but also that valuations have shifted to a higher level.

We show that unlisted infrastructure equity prices do not exist in a vacuum but are driven by factors that can be found across asset classes. Six factors are found to explain the market prices of unlisted infrastructure investments over the past 15 years: size, leverage, profits, term spread, value and growth. To these usual suspects, one can add sector and geographic effects. The result is an unbiased view of the evolution of prices (price-to-sales and price-to-earnings ratios).

We also find that on top of standard risk factors associated with most firms, sector-specific factors explain the level of prices and their recent evolution. For instance, renewable energy projects are found to have much higher price-to-sales ratios than average infrastructure companies, while social infrastructure has lower than average price-to-sales and roads valuations trend up and down with the economic cycle.

Our analysis documents the contribution of these factors to the evolution of average prices over the past fifteen years. Their effect is found to have been mostly persistent over this period i.e. individual risk premia have been stable albeit, in some cases, time-varying.

These effects are thus likely to continue driving prices in the future.

At the aggregate level, we document a degree of covariance between unlisted infrastructure prices and equivalent measures in public equity markets. At the sector level, patterns emerge with higher correlation with public markets in certain sectors more exposed to the economic cycle (e.g. Roads) and others experiencing peaks followed by a decrease in prices, like in the power sector.

A second phenomenon documented in this paper is a shift to generally higher price regime of the unlisted asset class during the 2008-2015 period. During those years, the effect of certain risk factors on prices become less powerful, notably leverage, as average prices increase seemingly independently of their risk profile.

During that period, the nature of investors active in the unlisted infrastructure market has also shifted: a period of price discovery (which has sometimes been called a bubble) led to lower required returns as the risk preferences of the average buyer of private infrastructure companies evolved. This period appears to end after 2015, when prices stabilise.

Infrastructure businesses are expected to deliver steady and predictable cash flows and to the extent that this is the case they should be expensive. Hence, after 10 years of price increases a price consensus may have been reached.

Executive Summary

Unlisted infrastructure prices will, in all likelihood, continue to be driven by common factors in the future, while the evolution of investor preferences will also determine the general level of prices and of the fair value of the unlisted infrastructure asset class.

Our results show that despite the evolution of investor preferences, systematic risk factors mostly continued to explain prices over that period, indicating that valuations remained, on average, rational and fair.

Approach: From Biased Transaction Prices to Unbiased Factors Prices

One of the most important requirements of the IFRS 13 framework is to calibrate valuations to observable market prices. Private infrastructure is an illiquid market and assets do not trade often. As a result, observable transaction prices are limited and are not representative of the investible market. But the prices and returns of unlisted infrastructure equity can be expected to be driven by certain common factors, including some that exist in other asset classes and are well-known.

To overcome this issue, we estimate the effect of six factors that impact observable transaction prices and apply these to the more representative EDHEC*infra* universe of unlisted infrastructure companies. We use statistical filtering techniques (Kalman filter) to capture the changing impact of these factors on prices evolves over time as investor preferences and market conditions change.

These factor effects are unbiased and statistically robust.

This allows us to compute thousands of "shadow prices" for those unlisted infrastructure companies that did not trade over the past 15 years. With this approach we can document the price dynamics of the unlisted infrastructure market over for the underlying population and not just for a biased sample of available transaction data.

We use a price-to-sales (PSR) ratio as a our valuation measure, which reflects the willingness of an investor to pay for future risky revenue growth and dividends, adjusted for risk. We find that PSRs are well behaved statistically and present multiple advantages over price-to-book and price-to-earnings ratios, not the least that they always have a positive sign.

A higher PSR indicates buyers are willing to pay more per dollar of average historical revenues, suggesting that these revenues are either expected to grow or considered more predictable. PSRs are also the standard metric used in international capital markets and may be compared directly with the equivalent ratio for public equity indices.

The 6 Risk Factors that Explain Unlisted Infrastructure Prices

Size: Previous research shows that small-cap stocks tend to outperform large-cap stocks because they have a higher exposure to systematic risk factors, undergo longer periods of distress in bad times, pose higher credit

Executive Summary

risk or are less liquid. In the case of infrastructure firms, larger assets are found to have lower prices i.e. higher returns. Effectively, size is a proxy of liquidity: larger infrastructure projects are more illiquid, complex to develop and the object of information asymmetries between buyers and sellers.

Leverage (credit risk): As for other firms, credit risk has an impact on equity investors in infrastructure, who take the risk of being 'wiped out' in the event of default. Infrastructure companies that have higher leverage – proxied by the ratio of total liabilities to total assets – thus have, on average, lower prices.

Profits: Also in line with theory, profitability impacts prices directly and positively. We find that the effect – proxied by the profit margin – is time varying and more important during bad times (the years following the financial crisis.)

Term spread: the value of infrastructure investments, with their high upfront capital costs, is determined by their long-term cash flows. They are therefore sensitive to interest (discount) rate changes. The term spread – the difference between long term and short-term interest rates – is found to have a negative impact on prices, also as theory predicts. In an international context, differences in term spread can also signal differences in country risk, especially when short-term rates are at the zero-lower bound, which is the case during most of the relevant period of observation.

Value: a value effect exists if companies are 'cheap' from one perspective or another. We look at infrastructure companies that report negative book values during their first ten years as a proxy of the 'value' period in their life-cycle. We find that the greenfield stage corresponds to a different level of prices than during the rest of the firm's life-cycle.

Growth: Infrastructure companies have limited growth opportunities as by nature they are designed to deliver individual investment projects with fixed revenues. Still, merchant infrastructure projects and corporates have opportunities to grow. For these companies, higher expected growth relatively increases prices. We also find that, in line with theory, realised revenue growth tends to have a positive effect on valuations.

Stylised Facts: The Dynamics of Unlisted Infrastructure Prices

Price-to-sales ratios of infrastructure companies are significantly higher than in public markets, irrespective market conditions. This reflects the ability of infrastructure companies to transform income into dividends, as highlighted in previous studies, payout ratios (dividend payouts over revenues) tend to be 4 to 5 times higher in mature unlisted infrastructure companies than in listed companies of equivalent size, leverage and profitability.

Price-to-earnings ratios tend to be much more volatile than in public markets. Indeed, payouts may be higher as share of revenues but they are also more variable

Executive Summary

as a the result of the significant financial and operational leverage that characterises infrastructure companies. Their large but mostly fixed production costs make any excess revenue a source of pure profit, but since any decline in revenues is not easily matched with a decline in production costs, profits can decline very fast as well.

For the most part, **the factors driving unlisted infrastructure secondary market prices make sense**: size, leverage, value or profitability have the signs predicted by theory and their effects are persistent, albeit variable, across time. This is significant to define an ex ante factor model of returns for the purpose of asset valuation (cf. the EDHECinfra Asset Valuation Methodology).

Price formation and discovery is slow: the factor effects documented above can take several years to change from one level to another, as transactions and investor preferences are processed by market mechanisms. This is partly the reflection of unlisted infrastructure status as a 'new' asset class, so that numerous transactions were necessary over many years for 'fair' prices – representing the willingness to pay of numerous buyers and sellers at one point in time – to emerge.

Prices do not react immediately to short-term variations in financial conditions: the swings in price-to-earnings are due to the fact that prices stayed on a steady increasing path for most of the period, while earnings swung up and down, especially in the merchant sector. This can be both a function of the slow processing of price information in a high illiquid market, as well as the reflection of the belief by buyers that most of the value of infrastructure companies is embodied in a long-term business model, which can be considered impervious to short-term volatility.

Valuations are not out of line with fair value: because price movements can be explained by systematic factors and the remaining variability of transaction prices appears to be idiosyncratic, prices can be said to have mostly evolved to reflect the preferences of market participants taking major risk factors into account. In other, words, pricing has remained rational and informed. The fact that prices have increased a lot over the past decade cannot simply be attributed to a 'wall of cash' effect in a market where many participants were chasing few available opportunities.

1. Introduction



1. Introduction

In this paper, we develop a systematic analysis of the factors driving the secondary transaction price of unlisted infrastructure investments.

Investors in unlisted infrastructure equity are faced with a dearth of data when assessing the fair value of their current or future investments. Unlisted infrastructure companies seldom trade, and finding listed proxies covering the investable unlisted universe has proven very challenging for both investors and prudential regulators, as recent academic research also attests (see Amenc et al., 2017, for a detailed study of the listed infrastructure universe).

Records of secondary market transactions do exist, but, as we document in this paper, this data is fundamentally biased. Unlisted infrastructure secondary market transactions do not occur uniformly in time and space but in certain markets and sectors at different points in time. This is the result of the highly illiquid nature of these asset, coupled with the role of public procurement policy in creating investable assets, which makes national markets more or less active over time.

These biases in observable prices are inescapable. Any collection of strictly observed transaction prices, even large in size, is unlikely to be representative of the investable market.

Using a *factor model* of prices is a solution to the bias and paucity of available transaction-price data. As long as such factors can be documented in a statistically robust and

unbiased manner, they can also be used to assess the fair value of unlisted infrastructure equity investments over time, whether they are traded or not.

One of the most important requirements of the IFRS 13 framework is to *calibrate valuations to observable market prices*, thus ensuring that estimated prices represent current investor preferences at the measurement time.

In what follows, we first use a large sample of actual transactions over the past 20 years to estimate the effect on price-to-sales ratios of a number of pricing factors. The choice of these factors is rooted in modern asset-pricing theory with a focus on the standard risk factors typically found in equity and bond markets, which are well documented in the asset-pricing literature but also incorporate aspects that are specific to infrastructure companies.

We use a dynamic method to estimate time-varying coefficients for a multifactor model of unlisted infrastructure equity prices.

While the sample of observable transactions is found to be serially correlated and biased in terms of industries and geographies, estimated coefficients are shown to be robust and unbiased.

These results provide us with important insights into the factors that effectively drive secondary market valuations for unlisted infrastructure equity investments and therefore which factor models should be

1. Introduction

used to estimate fair value for investors in unlisted infrastructure.

Finally, we apply this factor model to the EDHEC*infra* universe, a much larger sample of unlisted infrastructure firms that is designed to be representative of the investable market in the 20+ most active (principal) markets in the world. This allows us to compute thousands of “shadow prices” for those unlisted infrastructure companies that were not traded over the past 15 years.

We report broad market price ratios that are directly comparable to equivalent ratios reported for public equity markets such as the S&P500.

We find that unlisted infrastructure equity valuations have significantly increased in recent years, even though certain sectors, such as the power sectors, have gone through important periods of decreasing prices.

We also find that the movements of unlisted infrastructure equity valuations correlate somewhat with public equity markets.

The rest of this paper is organised thus: Chapter 3 describes our approach and data. Chapter 4 describes a dynamic framework for estimating the factors driving market prices when a limited number of transactions can be observed in time and space.

Chapter 5 focuses on the estimation of the relevant factors' effects, and the interpretation of those effects.

Chapter 6 presents the results of applying the estimated-factor model in a hedonic fashion to the EDHEC*infra* universe and describes estimated price trends in global markets as well as within various sectors or countries.

Chapter 7 concludes.

2. Literature: Risk Factors and Infrastructure Returns



2. Literature: Risk Factors and Infrastructure Returns

A few academic studies have tried to analyse the behaviour of infrastructure returns over time, as well as their associated characteristics, for portfolio investors.

For example, Wen Peng and Newell (2007), Inderst (2010), and Hartigan et al. (2011) evaluate the risk-adjusted performances of infrastructure investments over different periods of time, while Wen Peng and Newell (2007) and Bitsch et al. (2010) consider the inflation-protection characteristic that infrastructure investments are sometimes expected to provide. In addition, a number of papers also explore the potential diversification benefits for portfolio investors, including Wen Peng and Newell (2007), Finkenzeller et al. (2010), Bitsch et al. (2010), Newell et al. (2011), and Bird et al. (2014).

There is less research on the explanatory factors of unlisted infrastructure asset returns and prices. These could include traditional asset-pricing factors previously identified in the equity and bond literature such as size, value, or growth (see Martellini and Milhau, 2015, for an in-depth review), as well as more infrastructure-specific factors such as the firm lifecycle, leverage, geography or industry, and business model (see Blanc-Brude, 2013, for a detailed discussion of the types of risks found in infrastructure investments).

In what follows, we review some of the key ideas put forward in the finance literature about how certain systematic factors tend to explain the returns of investors in public or private companies, as well as any existing

findings or hypotheses about the factors found in unlisted infrastructure investments.

2.1 Size and Liquidity

Size has long been considered an important factor that helps explain the returns on stocks, bonds, and mutual funds (see for example Fama and French, 1993; Carhart, 1997). Empirical studies of public markets suggest that small-cap stocks tend to outperform large-cap stocks, and they sometimes explain these findings by arguing that small-cap stocks have higher exposure to systematic risk factors, undergo longer periods of distress in bad times (Fama and French, 1993), pose higher credit risk (Vassalou and Xing, 2004a), or are less liquid (Amihud and Mendelson, 1986). The impact of relative liquidity between stocks on returns is a potential discriminating factor, and typical measures of liquidity include the "marginal cost of trading" or the "relative fixed cost of trading" (Brennan and Subrahmanyam, 1996).

In the case of infrastructure firms, size measured by the book value of assets varies considerably, from basic renewable-energy projects requiring less than 50 million dollars of capital to utilities and megaprojects demanding billions of dollars of investment. Moreover, insofar as infrastructure companies can be divided between projects and corporates, the latter tend to be much larger by size.

Existing research on the risks found in infrastructure projects and companies suggests that risk should be an increasing function of size (see for example Priemus et al.,

2. Literature: Risk Factors and Infrastructure Returns

2008). Larger projects are more complex to build and operate and, by nature, require larger sunk costs, which are risky. Conversely, smaller infrastructure companies tend to be single-project vehicles and the most highly leveraged, which is typically interpreted as a signal of low asset risk (see below).

With unlisted infrastructure companies, the costs of trading are partly related to investment size. Hence, size may also be a proxy of liquidity premia. Indeed, infrastructure companies are also famously illiquid. Project-development times are long (construction periods range between two and ten years) and transactions require lengthy and costly due diligence. Capital expenditure is sunk in immobile, relationship-specific (single-use) assets.

Hence, we can expect larger private infrastructure companies to be priced at a discount both because they represent lumpy and risky sunk costs and because the cost of buying and selling is relatively high compared to smaller, simpler infrastructure assets.

Empirically, very few studies have considered the relationship between size and the returns of infrastructure investors.

Using listed infrastructure data, Ammar and Eling (2015) analyse US infrastructure stocks within the utilities, telecommunication, and transportation sectors from 1993 to 2011 and report a significantly negative relation between size and infrastructure returns, that is, larger capitalisations tend to have lower

returns, consistent with Fama and French (1993) for the rest of the stock market.

The literature on unlisted infrastructure is rather inconclusive: Using a data set of global infrastructure and noninfrastructure investments made by private funds, Bitsch et al. (2010) find no significant relationship between the size of infrastructure deals and their returns. They report a positive correlation coefficient between size and the internal rate of return (IRR) of infrastructure deals, at 2.24 compared to a coefficient of 2.81 for noninfrastructure deals, but neither are statistically significant. Conversely, Humphreys et al. (2016), using data about unlisted infrastructure transaction prices (EV/EBITDA multiples) do find that large-cap infrastructure assets (greater than USD 1 billion) are traded at higher multiples than the sector average range. However, this positive correlation between total assets and enterprise value (EV) is a mere accounting identity: because of the large share of debt in the EV of infrastructure companies, which is accounted for at its face value, larger firms by book value tend to trade for larger sums.

Overall, based on the theoretical insights above, **we expect size to be a proxy of liquidity risk in unlisted infrastructure and to command a positive premium**, that is, larger firms should, controlling for other factors, have a lower price of equity per dollar of revenues or earnings. This is consistent with the logic of the size factor in public markets, that is, size creates variable exposures to systematic risk factors but in this case

2. Literature: Risk Factors and Infrastructure Returns

larger firms should outperform smaller ones (controlling for other factors, like leverage).

2.2 Value and Growth

A “value” stock must be inexpensive by some measure, for example, its price-to-book ratio. As a risk factor, the existence of a value effect also implies a systematic effect to which value stocks are more exposed than growth stocks. For example, Fama and French (1992) and Vassalou and Xing (2004b) argue that firms with negative book-to-market ratios have high average returns, that is, financial distress leads to higher required returns, as with junk bonds. Overall, the argument is made that value firms are riskier in bad times (Petkova and Zhang, 2005), for example, because they cannot adjust their investment decisions with the business cycle. In other words, given expected earnings and expected changes in book-to-equity ratio (investment), a lower price-to-book ratio implies higher required return.¹

Infrastructure companies have limited growth opportunities. Infrastructure-project companies are designed to implement individual investment projects (albeit sometimes with multiple phases). Infrastructure corporates have more opportunities to grow, either because they are called to meet new demand (larger airports and water networks) or because they can acquire other firms while still being categorised as infrastructure.²

Even in the latter case, infrastructure investments are sunk and committed over long

periods. Following Petkova and Zhang (2005), infrastructure firms cannot adapt their level of investment to the business cycle. In effect, they have a high level of *operational leverage*. Hence, to the extent that they are exposed to this cycle, as merchant power plants or toll roads are, they will experience relatively more financial distress than infrastructure firms that are less exposed to the business cycle, such as “contracted” projects.

Infrastructure-project companies also tend to have negative book equity in their earlier years, when they are still being developed at a “greenfield” stage. Then they may represent “value,” as the business is being built, literally, from the ground up. It may be tempting to call greenfield infrastructure companies “growth” assets, but because long-term commitments are required for infrastructure investments to take place, the future value of these companies is embedded in the decision to start the investment. The sunk and long-term nature of capital expenditure during the development phase is what makes the value of infrastructure investments risky, and it should call for higher returns.

Still, as suggested above, some infrastructure companies, such as merchant infrastructure companies, do have good growth prospects relative to others.

The combination of early-stage development, sunk costs, and the fixed nature of the business makes a direct comparison with “value” and “growth” stocks difficult. Rather, we can ask: When are infrastructure companies relatively more expensive? We

1 - The standard Gordon model can be written $\frac{P_t}{B_t} = \sum_{s=1}^{\infty} \frac{E(Y_{t+s} - \Delta B_t)}{B_t(1+r)^{s-t}}$, with P_t and B_t the price and book value of equity, respectively; Y_t the firm's earnings; and r the discount rate or required return.

2 - In the late 1990s, UK water utilities expanded aggressively in South East Asia and China. They have since retreated back to their home market.

2. Literature: Risk Factors and Infrastructure Returns

expect the unfolding of the firm's lifecycle and the sequential resolution of uncertainty to gradually reveal the value of infrastructure companies, and expect operating, brown-field companies to be more predictable and expensive.

Thus, we expect unlisted infrastructure investments to be **relatively cheaper and thus command higher returns at the greenfield stage** but also when they experience limited financial distress because of their high level of operational leverage.

2.3 Credit Risk

Several papers examining leverage ratios in the infrastructure sector report that infrastructure companies are typically highly leveraged: Bucks (2003) finds an 83 percent leverage ratio for water and energy firms, while Beeferman (2008) also reports very high average leverage ratios, ranging from 50 percent for transportation assets to 65 percent for utilities and 90 percent for social infrastructure. More recently, using a global data set going back 20 years, (Blanc-Brude et al., 2018b) document similar levels of leverage in infrastructure projects.

Bird et al. (2014) report a positive influence of leverage on the excess return of Australian unlisted infrastructure utilities during the 1995–2009 period but note that the correlation is not statistically significant. Ammar and Eling (2015) find a significantly positive relationship between leverage and listed infrastructure returns, supporting the

rationale that the borrowing of outside capital increases the return on equity.

From a theoretical angle, the relationship between leverage and risk in infrastructure firms is U-shaped. Low leverage signals lower default risk and can be expected to have a positive impact on asset prices. However, infrastructure projects are often delivered using stand-alone investment structures (special-purpose vehicles) created and financed specifically to deliver a single asset in the context of a pre-existing network of contracts that typically creates long-term revenue visibility and mitigates most of the development and operational risks that equity investors and lenders are typically exposed to. As a result, high-leverage is typically a signal of low asset risk in project finance (Esty and Megginson, 2003). For instance, Blanc-Brude et al. (2018a) show that leverage in infrastructure-project finance is an inverse function of credit risk: companies with a lower probability of default (measured by the volatility of their debt service cover ratio) tend to have higher levels of senior debt relative to equity.

Still, credit risk impacts equity investors who take the risk of being "wiped out" in the event of a hard default. We can thus **expect a credit risk factor to discriminate between the expected returns and therefore the price paid by equity owners.**

2.4 Interest Rates

Interest rates can impact asset prices in multiple ways: they impact the discount rate

2. Literature: Risk Factors and Infrastructure Returns

found in any pricing equation but also capture investors' preferences for investing in long-term assets.

Most *infrastructure investments* are time-bound single-project companies and thus have a maturity even for equity investors. Hence, the value of such investments has a straightforward duration, and we can expect interest rates to have an impact on transaction prices. Both Bitsch et al. (2010) and Ammar and Eling (2015) find that infrastructure companies are sensitive to interest rate movements.

Next, the "term" premium is the excess return from holding a long-term bond over a short-term one. For example, owners of long-term bonds should expect to receive a higher return than if they had invested in a short-term bond because of long-term inflation risk. A higher *term spread* (the difference between long- and short-term interest rates) can signal lower willingness to invest in long-term assets compared to short-term ones. Conversely, if investors have a preference for long-term assets like infrastructure, long-term yields decrease and so should the term spread. The term spread may also increase because short-term interest rates are maintained at artificially low levels by monetary authorities, in which case the long-term rate may look disproportionately expensive. Still, **we expect a negative relation between the term spread and infrastructure asset prices.**

Finally, in an international setting, difference in interest rates or term spreads can also capture differences in required country risk

premia and justify price differences for otherwise similar assets.

2.5 Geographic and Sector Effects

Most investable infrastructure is procured by the public sector of a given national or subnational entity. Hence, country effects can also be expected to be significant if different governments have different track records in respect to their contractual commitments, change infrastructure-related and other regulations, and choose to procure infrastructure for which there is ultimate demand, especially in the case of merchant infrastructure companies. Governments can also represent varying levels of counterparty risk in contracted infrastructure.

As a risk factor, industry effects imply that certain sectors create higher systematic risk exposures for investors. This is driven by the partial overlap between certain sectors and business models and corporate structures, for example, the immense majority of network utilities (the eighth industrial superclass under *TICCS*³) are large regulated corporates.

In previous research, Bitsch et al. (2010) finds that infrastructure investments made in Europe significantly outperform those made in other regions, with a difference in IRR of 35.4 percent. They also study the differences in returns within the infrastructure sector and report that investments made in transportation (e.g., airports, ports, or toll roads) exhibit higher IRRs than other sectors, such as natural resources or energy.

3 - *TICCS*TM is a taxonomy of infrastructure investments put forward by EDHEC*infra* and reviewed annually by a committee of industry representatives. It can be accessed on the EDHEC*infra* website.

2. Literature: Risk Factors and Infrastructure Returns

Overall, we expect sector and geographic control variables to have a degree of explanatory power on observed transaction prices, even though their interaction with factors such as size and leverage should be taken into account to control for significant heterogeneity between sectors and countries.

2.6 Lifecycle Effects

All firms have a lifecycle, but existing research focuses on the listed equities and bonds of mature companies. Moreover, the lifecycle of infrastructure companies changes from an initial period of sinking capital expenditure into a relationship-specific, immobile, hard asset to one of operating this asset for several decades. Single-project companies are also characterised by their finite life.

As discussed above, this change can be considered to coincide with the *value* and *term* effects: during the initial development stage in their lifecycle, infrastructure firms can be conceived of as relatively “cheap” and are also relatively more exposed to interest rate risk, in the case of infrastructure projects with a finite life.

2.7 Business-Model Effects

As argued elsewhere, infrastructure companies can be broadly categorised by families of “business models”: contracted, merchant, and regulated (this is the first *TICCS*TM pillar).

Contracted infrastructure is less exposed to changes in the business cycle and should

therefore be more valuable to investors (and receive lower returns), since it is expected to continue paying in bad states of the world. Regulated assets, while less predictable than contracted ones due to the regular resetting of tariffs by public regulators, follow a cycle that is mostly uncorrelated with the state of the economy and should also be considered more valuable if they can payoff in bad times.

Merchant infrastructure companies can be expected to be more exposed to the fluctuations of the business cycle and to macroeconomic shocks.

Relative to contracted infrastructure firms, merchant and regulated business models can thus be expected to partly coincide with a *growth factor*.

Using listed infrastructure assets, Bird et al. (2014) compare the performance of regulated assets (defined as direct investment in the listed infrastructure and utility sectors in the US and Australia) and unregulated assets (proxied by the broad market index). The key findings indicate that the regulated assets outperform the unregulated assets. As a result, regulatory risk premium is suggested to be a factor that could help explain the variation in infrastructure returns.

In conclusion, a number of factors can be expected to drive the equity prices of unlisted infrastructure companies. Most of them come directly from the asset-pricing literature developed using stock and bond market data and refer to a handful of well understood economic mechanisms. Several

2. Literature: Risk Factors and Infrastructure Returns

other factors are more specific to infrastructure companies and sectors but can be expected to partly overlap with traditional factors, for example, *value* and the *lifecycle* effect or *credit risk* and business models. To the extent that these factors correlate with each other they should be used together in a multifactor model of transaction prices. We discuss our approach and data in the next chapter.

3. Approach & Data



3. Approach & Data

3.1 A Hedonic Approach

As suggested in the introduction, the main difficulty facing econometric research on the price formation of unlisted infrastructure investments is the paucity of transaction prices. On average, unlisted infrastructure companies are bought or sold in a secondary market once in their lifetime (see EDHEC*infra* Index Methodology for more details).

In effect, many of these companies never change hands during the life of the investment. This effect is compounded by the tendency of numerous long-term investors to want to hold such investments to maturity.

As a result, any time series of unlisted infrastructure secondary market transactions, however large, can be expected to be biased in multiple ways: different types of infrastructure projects and companies trade in certain places at certain points in time, and observable transaction prices are not likely to form a representative set of prices of the investable universe.

Moreover, the reporting of unlisted infrastructure secondary market transactions can be expected to be limited and biased due to the private and often confidential nature of this information.

As a result, to document both relevant pricing factors and market dynamics, we proceed in two steps.

First, using a reasonably large sample of transaction prices and certain control variables, we

aim to estimate an *unbiased* set of factors (coefficients) that explains the variance of observable transaction prices.

Next, using a much larger dataset for a representative time series of investable infrastructure projects and companies since the year 2000, most of which have not been bought or sold, we use the factor effects estimated from actual transaction prices to derive a "shadow" price for each of the companies in this more representative dataset at each point in their lifetime.

This *hedonic* approach allows documenting the price dynamics of the unlisted infrastructure market over the past 15 years for the underlying investable population and not just for available transaction data.

3.1.1 Choice of Price Ratio

To allow direct comparisons between transactions, we scale transaction prices by the firm's revenues to compute the price-to-sales ratio (PSR).⁴

We choose to model PSRs rather than price-to-book (PBR) or price-to-earnings (PER) ratios partly for their statistical stability and robustness and partly because they are well suited to understanding infrastructure companies.

Private infrastructure companies can have negative equity book values or earnings, sometimes for long periods due to their lengthy development phases and high leverage.⁵

4 - For revenues we use the past four quarters of the sum of operations and financial revenues.

Financial revenues are an important part of revenues in investments categorised as financial leases, such as public-private contracts (PPPs) in European markets.

5 - Of course, they may also have negative book values or earnings when they run into financial difficulties.

3. Approach & Data

For instance, in the EDHEC*infra* universe, tracking 650+ firms over the past 20 years in 20+ countries, we observe negative book values approximately 15 % of the time.

This creates highly nonlinear relationships in the data, for example, between price-to-book and leverage. In standard equity analysis, negative price-to-book values are often considered not meaningful.

Conversely, sales are generally more stable than earnings, which are impacted by operating and financial leverage. As a result, the PSR is more amenable to statistical modeling than PBRs or PERs.

Because revenues are always positive, the logarithm of unlisted infrastructure PSRs, although it is not strictly Gaussian, exhibits strong regularities, as shown in figure 2.

The PSR is also a standard metric used in international capital markets and may be compared directly with the equivalent ratio for public equity indices.

A higher PSR simply means that buyers are willing to pay more per dollar of average historical revenues, suggesting that these revenues are either expected to grow or considered more predictable.

PSR are typically used to evaluate new firms that do not have positive earnings and are expected to see strong future revenue growth.

But they are also well-suited to infrastructure investments that, by design, have

very limited growth options. A focus on the ability of infrastructure companies to generate predictable income seems appropriate.

Moreover, by focusing on PSR, we can control for the effect of leverage on prices explicitly rather than through its impact on earnings in the cash-flow waterfall. This is important since levels of leverage are high but also sector specific in infrastructure financing, as discussed in chapter 2.

Formally, extrapolating from the usual Gordon model, the PSR is written:

$$\frac{\text{Price}}{\text{Sales}} = \frac{PM \times (1 - RR) \times (1 + g)}{r - g} \quad (3.1)$$

where *PM*, the profit margin, is the ratio of earnings to sale; *RR* is the dividend retention rate; *g* is the expected sales growth; and *r* the expected return.

Hence, the PSR can be expected to increase with expected sale and profit margin growth and to decrease with the required rate of return or discount rate. Following asset-pricing theory, as discussed in chapter 2, *r* should be impacted by several factors, including the size and term effects.

In the next section we describe the data used in this study.

3. Approach & Data

3.2 Data

3.2.1 Available Price Data

Using the EDHEC*infra* database, we first build a dataset of transaction prices for the equity value of unlisted infrastructure companies.⁶

The equity prices recorded correspond to the price paid for 100% of the equity share capital of a company, including any shareholder loans invested by the firms' owners.⁷

As suggested above, this sample of prices is biased by the infrequent trading of infrastructure companies as well as various reporting issues. Figure 1 shows, on the left side, the distribution of transaction price data available by country (top left) and sector (bottom left) compared to the distribution of the entire EDHEC*infra* universe, on the right side. For the 1995–2017 period, the EDHEC*infra* database yields 680 secondary market transactions.

As figure 1 illustrates, this sample of available transaction prices tends to overrepresent the UK, French, and Spanish markets as well as social-infrastructure and renewable-energy transactions, arguably smaller transactions and relatively more liquid investments than larger infrastructure projects and companies, taking place in some of the most active markets for unlisted infrastructure investment over the past 20 years.

Transaction in highly visible sectors such as airports and telecoms are also likely to be reported more often than their identified share of the investable universe warrants.

Table 1 shows the number of observable transaction prices by country and sector respectively and the equivalent number of shadow prices that can be estimated using the entire universe. Estimated shadow prices will be used to report 15-year price trends in chapter 6.

Finally, we compute PSRs by taking the ratio of transaction prices and the sum of financial and operating revenues, both converted into USD using the 90-day moving-average exchange rate at the time of the transaction.

3.2.2 Explanatory Variables

Following the literature reviewed in chapter 2, as well the justified PSR expression above (equation 3.1), candidate explanatory variables of secondary market transaction price ratios include the following **fundamental factors**:

1. The **size** effect on prices can be expected to impact expected returns r and is proxied using total assets;
2. Financial **leverage** can be expected to impact dividend payout rates (or retention rates) and discount rates and is proxied using the ratio of total liabilities to total assets;
3. **Profitability** should impact the PSR directly and positively and is proxied using profit margin;
4. The **term** factor impacts r in equation 3.1 through investor time preferences and is proxied by the difference between long- and short-term interest rates⁸ at the time and in the country of the transaction. Because it incorporates the level of long-

6 - The EDHEC*infra* database is the largest database of financial data on infrastructure investments in the world. It is populated with information contributed by investors in infrastructure equity and debt and the detailed audited accounts of hundreds of individual infrastructure companies. The data is collected and cleanED following a manual process of aggregation and verification and includes data provided by investors and fund managers, banks and multi-lateral agencies as well as audited accounts, freedom of information requests, news stories, etc.

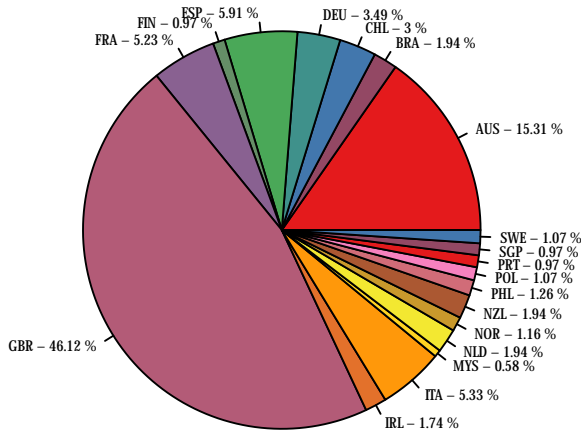
7 - Such quasi-equity is often found in infrastructure-project financing and must be taken into account to fully capture the size of unlisted infrastructure equity investments and make them comparable with more standard corporate structures.

8 - The *term spread* is built by computing the difference between the 20-year and the 3-month yield on public bonds.

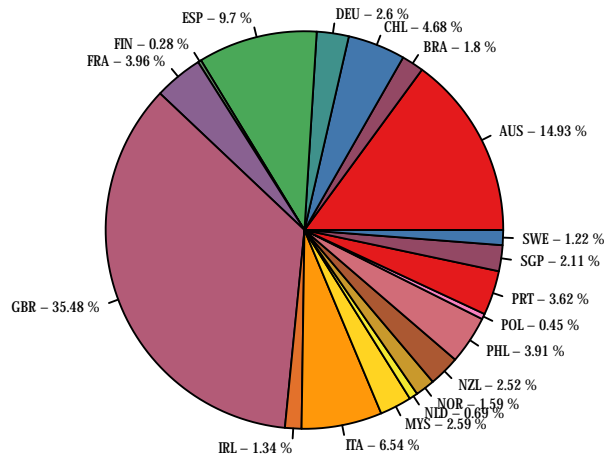
3. Approach & Data

Figure 1: Distribution of Available Transaction Data vs. the EDHECinfra Universe, 2000-2017

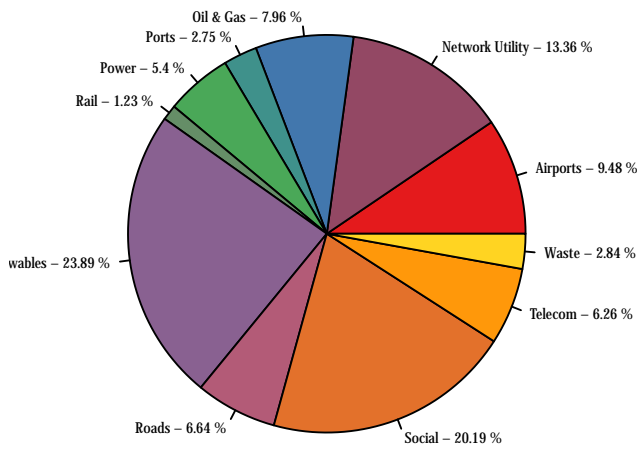
Secondary Market Transaction Prices by Country



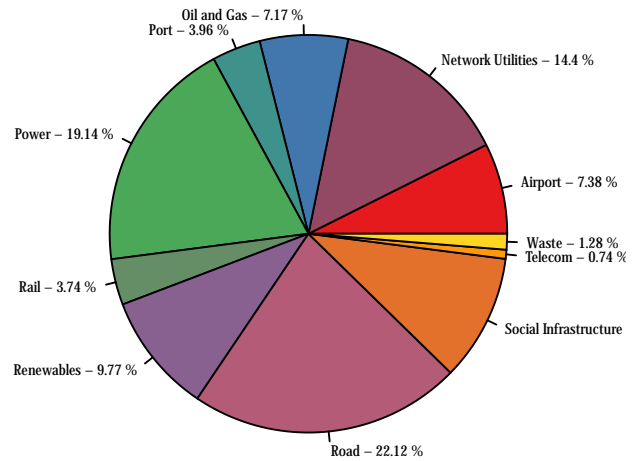
EDHECinfra Universe by Country



Secondary Market Transaction Prices by Sector



EDHECinfra Universe by Sector



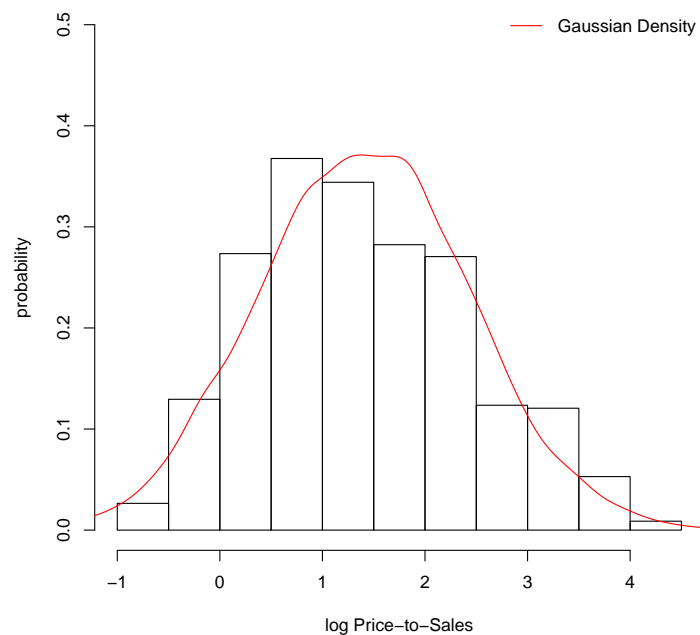
3. Approach & Data

Table 1: Number of Observed Prices and Potential Shadow Prices in the EDHECinfra Universe by Country and Sector

Sectors	Realised	Shadow
Airports	100	467
networkU	141	921
ong	84	453
ports	29	258
power	57	1244
rail	13	238
Renewables	252	669
Roads	70	1456
Social	213	652
Telecom	66	46
Waste	30	84

Countries	Realised	Shadow
AUS	158	896
BRA	20	113
CHL	31	600
DEU	36	149
ESP	61	595
FRA	54	251
GBR	476	2231
IRL	18	83
ITA	55	414
MYS	6	166
NLD	20	42
NOR	12	102
NZL	20	163
PHL	13	217
POL	11	29
PRT	10	231
SGP	10	132
SWE	11	74

Figure 2: Histogram of the Logarithm of Input Price-to-Sales Ratio Data



3. Approach & Data

term interest rates, this metric is also a proxy for *country risk*;

5. A **value** effect impacts expected sales growth through the sequential resolution of uncertainty that characterises maturing investments with large initial sunk costs and long repayment periods. The early development stage of infrastructure companies is proxied by creating a *value* flag for "greenfield" companies that have been incorporated for 10 years or less and also report negative book equity.
6. Also in line with the justified PSR formula, **growth** effect can be expected to *relatively* increase the price of those merchant infrastructure companies that have a higher growth potential (e.g., airports) than contracted or regulated firms, which receive a revenue that is a function of their design capacity and cannot grow beyond that level.

Descriptive statistics for these potential factors are reported in chapter 5 in table 2. Next, to estimate the effect of these factors on transaction prices in a context where reported price data is limited and biased, we use a dynamic regression model described in chapter 4.

4. Dynamic Modeling



4. Dynamic Modeling

As discussed in chapter 1, the objective of this paper is to empirically identify relevant explanatory factors of unlisted infrastructure companies' equity prices. Using the secondary market and company-level cash flow data described in chapter 3, the empirical challenge is to estimate the impact of the various factors discussed in chapters 2 and 3.

Factor models typically represent the relationship between the quantity of interest (here, price-to-sales ratios) and various explanatory variables as a *linear* function. In this setting, each factor or coefficient represents an independent component of transaction prices.

The level of these coefficients can also be expected to vary over time: for example, the impact on transaction prices of financial leverage depends on buyers and seller preferences for credit risk (as a factor of equity risk).

Over time, each of these coefficients may evolve in a highly nonlinear fashion as investors' willingness to buy or sell a firm with a certain level of financial leverage at a given price varies as the economic and financial cycle unfolds.

In what follows, we describe a dynamic linear model specifically suited to estimating the value of time-varying coefficients of the factors that explain secondary transaction prices.

4.1 Model Setup

At its simplest, the relationship between observable transaction prices and their explanatory factors is described using a linear model such as:

$$Y_t = \beta_1 + \sum_{k=2}^K \beta_k x_{k,t} + \varepsilon_t, \text{ with } \varepsilon_t \stackrel{iid}{\sim} \mathcal{N}(0, \sigma^2) \quad (4.1)$$

where Y_t is the price process at time t ; $x_{k,t}$ is a vector of K explanatory variables such as the firm's size, leverage, etc. at the time of measurement; and β_k are the corresponding $k = 1 \dots K$ coefficients or pricing effects.

However, the assumption of independently distributed errors $\varepsilon_t \stackrel{iid}{\sim} \mathcal{N}(0, \sigma^2)$ is unlikely to be realistic if measurements (recorded prices) are taken over time.

For instance, the impact of leverage, size, or certain country and sector effects on transaction prices, even if they can be assumed to be independent from one another, are likely to be *autocorrelated*, that is, not independent from one transaction to the next.

Moreover, these factors are likely to be *nonstationary*, that is, to evolve over time as investor preferences and market conditions evolve.

Hence, let's introduce a temporal dependence between Y and x_k by considering that coefficients may evolve over time. That is,

$$Y_t = \beta_{1,t} + \sum_{k=2}^K \beta_{k,t} x_{k,t} + \varepsilon_t, \text{ with } \varepsilon_t \stackrel{iid}{\sim} \mathcal{N}(0, \sigma^2) \quad (4.2)$$

4. Dynamic Modeling

The evolution of the coefficients is modeled as:

$$\beta_{k,t} = \beta_{k,t-1} + w_{k,t}$$

with $k = 1 \dots K$ and $w_{k,t}$ independent.

With time-varying and explicitly autocorrelated coefficients $\beta_{k,t}$, equation 4.2 can be rewritten as a system of two equations.

Defining $\theta_t = [\beta_{1,t} \dots \beta_{K,t}]'$, and $F_t = X_t'$, the linear relationship between transaction prices and their factors is:

$$Y_t = F_t \theta_t + v_t, \text{ with } v_t \stackrel{iid}{\sim} \mathcal{N}(0, V_t) \quad (4.3)$$

$$\theta_t = G_t \theta_{t-1} + w_t, \text{ with } w_t \stackrel{iid}{\sim} \mathcal{N}_k(0, W_t)$$

with $V_t = \sigma_t^2$, the variance or noise of the pricing equation and W_t the (co-)variance (matrix) of the model's K coefficients.

Equation 4.3 is a state-space or hidden Markov chain model⁹ consisting of an *observation* equation $Y_t = F_t \theta_t + v_t$ – here, the relationship between observable prices and their explanatory variables – and a *system* or state equation capturing the autoregressive and time-varying nature of a vector of the model's coefficients, θ_t .

Note that with $G_t = I$, the identity matrix, and W_t diagonal, the regression coefficients are represented as independent random walks. In other words, each factor's impact on prices is serially correlated, but its evolution is independent from that of other factor prices.

If some of the explanatory variables of the model are not independent from other effects, as we report in the next section with respect to the joint impact of company size, for example,

this can be captured by the covariance components of W_t , which model 4.2 did not allow.

Also note that if $W_t = 0$, that is, if there is no innovation over time in the regression coefficients, equation 4.3 is equivalent to equation 4.1, the static model.

To summarise, the standard linear relationship between prices and pricing factors described in equation 4.1, which describes the average effect of K factors on transaction prices, can be generalised using a state-space model to represent the evolution of each factor on prices over time.

In this dynamic setting, an observable process Y_t (transaction prices) is driven by a latent (unobservable) process θ_t up to (independent) Gaussian errors. This latent process has autoregressive dynamics of order 1, that is, it only depends on its own previous realisation up to some innovation over time.

Next, we discuss how Bayesian techniques can be used to estimate the K coefficient estimates each time new observations – here new transaction prices – become observable, thus tracking the time-varying impact of each factor on the average level of prices.

4.2 Model Estimation

State-space models, such as the one described above in equation 4.3, present several advantages: their dynamics follow a so-called Markov process¹⁰, and observations are assumed to be *conditionally independent*,

9 - State-space models represent a time series (here, the prices or price ratios corresponding to individual transactions) as the results of a dynamic system that can be made of multiple components including trend, regressive, or cyclical components. Such models can be used to capture nonstationary effects, structural breaks, and other patterns affecting the process over time (see Petris et al., 2009, for a detailed discussion).

10 - Any process by which $\pi(y_t | y_{1:t-1}) = \pi(y_t | y_{t-1})$, i.e., a so-called memory-less process by which all relevant information up until $t - 1$ is encapsulated in y_{t-1} .

4. Dynamic Modeling

that is, conditioning on the state θ , any price y_t is independent of previous realisations $y_{1:t-1}$. As a result, state-space models can be computed recursively starting from an initial or prior density of the state vector.

We return below to how the initial prior of the state vector might be set. First, we describe the recursive process by which the *posterior* state of the system can be estimated using the Kalman filter.

First, before the next transaction can be observed, a prior of the state vector is given by

$$\theta_{t-1}|y_{1:t-1} \sim \mathcal{N}_k(m_{t-1}, C_{t-1})$$

Using this prior estimate of θ_{t-1} , the system equation is used to predict the state of the system (the K coefficients of the model) for the next transaction, given the information available up until that transaction $y_{1:t-1}$.

Using equation 4.3, it can be shown that the *predictive distribution* of θ_t given $y_{1:t-1}$ follows a Gaussian process with parameters:

$$\begin{aligned} a_t &= E(\theta_{t-1}|y_{1:t-1}) = G_t m_{t-1}, \\ R_t &= \text{Var}(\theta_{t-1}|y_{1:t-1}) = G_t C_{t-1} G_t' + W_t \end{aligned} \quad (4.4)$$

If $G_t = I$, as suggested above, the predictive state vectors at time t simply are the $\beta_{k,t-1}$ coefficients estimated for the previous transaction.

Next, the predictive distribution of the new transaction price is derived using the relevant variables x_t at the time of the new transaction.

The one-step-ahead (predictive) distribution of Y_t given $y_{1:t-1}$ also follows a Gaussian process with parameters:

$$\begin{aligned} f_t &= E(Y_t|y_{1:t-1}) = F_t a_t, \\ Q_t &= \text{Var}(Y_t|y_{1:t-1}) = F_t R_t F_t' + V_t \end{aligned} \quad (4.5)$$

Finally, in the last step of the Kalman filter, the *posterior* or filtering distribution of the state vector $\pi(\theta|y_{1:t})$ is computed using the law of conditional probability.

The *filtering* distribution of θ_t given $y_{1:t}$ is a Gaussian process with the parameters

$$\begin{aligned} m_t &= E(\theta_t|y_{1:t}) = a_t + R_t F_t' Q_t^{-1} e_t \\ C_t &= \text{Var}(\theta_t|y_{1:t}) = R_t - R_t F_t' Q_t^{-1} F_t R_t \end{aligned} \quad (4.6)$$

where $e_t = Y_t - f_t$, the so-called forecast error, is the difference between the predicted price in the second step (before observing the transaction) and the realised value of Y_t .

This provides a correction of the initial estimate of the K coefficients, which is a function of how much the new transaction price differs from what the prior estimate of θ suggested. The weight given to this correction to the estimate of θ is called the Kalman Gain and is written

$$K = R_t F_t' Q_t^{-1}$$

that is, the uncertainty (or variance) of the measurement (V_t , which determines Q_t) and the variance of the state itself (W_t , which determines R_t).

The ratio W/V is known as the signal-to-noise ratio and reflects the ability of the model to learn from new data. If the system/state

4. Dynamic Modeling

variance is very low (i.e., its precision is very high) then new observations affect the estimate of θ less than if the state is considered as highly undetermined.

In effect, the posterior expected value of θ_t is

$$m_t = K_t y_t + (1 - K_t) m'_{t-1} x_t$$

which is a weighted average of the new price observation y_t and its predicted expected value before observing the new data.

This *posterior* estimate of the state vector (of model coefficients) combines the difference between actual and predicted price with the relative uncertainty of the state and observation to *optimally* learn about the evolution of model coefficients in each transaction without discarding too much of the information captured by the prior distribution.

4.3 Recursion and Initial Prior

4.3.1 Prior values of m_{t-1} and C_{t-1}

Note that the recursive nature of the estimation is made possible by the assumption of conditional independence of Y_t given θ_t . That is, at time t , before new information arrives, all information available about the process Y is encapsulated in the latest estimate of the distribution of θ_{t-1} .

Each such estimate can thus become the prior distribution of θ_t in the next iteration without loss of information, that is,

$$\pi(y_t | \theta_{t-1}, y_{1:t-1}) = \pi(y_t | \theta_{t-1})$$

Initiating the recursive estimation of the vector of $\beta_{k,t}$ coefficients does require an initial prior θ_0 .

In this case, setting prior values for the state vector of model coefficients θ_t is straightforward: with the evolution of each coefficient $\beta_{k,t}$ modeled as a random walk with independent noise, the prior value of each coefficient is simply set to zero.

This prior mirrors the null hypothesis of the t-test applied to the coefficients of static linear models: until proven otherwise by observable inputs, the effect of each factor is assumed not to exist.

Likewise, we start from the premise that the initial values of the state vector are unknown and set the variance of each coefficient to be a high value such as 10^7 .

Hence, $\theta_{y_0} \stackrel{iid}{\sim} \mathcal{N}_k(m_0, W_0)$ with $W_0 = \text{diag}(10^7 \dots 10^7_k)$.

This can be described as an "agnostic" prior: we do not make any economically meaningful assumptions about the density of the coefficients in equation 4.3 until we observe some transaction data.

4.3.2 Meaning of V_t

Finally, we will need to set a estimate for V_t , the "noise" level of the price observations. While the notion of noisy observations typically refers to physical measurements (e.g., distance or speed), the notion of noisy price observations also makes sense from the standpoint of asset-pricing theory. Indeed, while

4. Dynamic Modeling

actual transaction prices encapsulate market prices of risk required by the average investor (i.e, the effect of systematic risk factors on expected returns and transaction values), they also include idiosyncratic "noise" created by individual investor preferences. This is especially relevant in private, relatively illiquid and *incomplete* markets where the law of one price cannot be expected to hold at all points in time.

In effect, the multifactor model of prices represented by equation 4.2, which the filtering process above aims to estimate, represents the combination of each factor's effect on average transaction prices only and treats the idiosyncratic component of transaction prices as white noise V_t .

Whether the model's residuals are indeed white noise (zero-mean, Gaussian) is an important test of the robustness of the coefficient estimates (we report these results in chapter 5).

4.4 Smoothed Coefficient Estimators

Kalman filtering, as outlined above, aims to estimate the value of the state vector up until the most recent observation and update the posterior density of the state accordingly. This is useful for an understanding of the present state of system given available information at time t .

However, since we aim to document the evolution of the factors impacting unlisted infrastructure prices over the entire sample period, we can also use each filtered estimate

of the K coefficients to derive "smoothed" coefficient estimates that take all realised information, up until the last observation time T , into account.

Hence, a retrospective time sequence of state vectors can be estimated for each transaction date in the past given the data available up until now, $y_1 \dots y_T$. This allows for the complete study of the system underlying the realised observations and is solved by recursively computing the conditional distribution of $\theta_t | t_{1:T}$ for any $t < T$ and estimating backward previous states.

With Gaussian priors, the computations are straightforward, and, using the notation for equation 4.3, it can be shown (Petris et al., 2009) that if the latest state estimate is

$$\theta_{t+1} | y_{1:T} \sim \mathcal{N}(s_{t+1}, S_{t+1})$$

then,

$$\theta_t | y_{1:T} \sim \mathcal{N}(s_t, S_t)$$

with the parameters:

$$s_t = m_t, C_t G'_{t+1} R_{t+1}^{-1} (s_{t+1} - a_{t+1}) \quad (4.7)$$

$$S_t = C_t - C_t G'_{t+1} R_{t+1}^{-1} (R_{t+1} - S_{t+1}) R_{t+1}^{-1} G_{t+1} C_t$$

Typically, the smoothed state estimates have lower variance (S_t) than filtered estimates (C_t) due to the fact that smoothed estimates are conditioned on the entire data up until time T . Hence, in an historical analysis such as the one conducted in this paper, smoothed estimates provide the best possible signal content and optimal estimates of the model's coefficients. They are reported in the next chapter for our model of the determinants of prices in unlisted infrastructure equity transactions.

5. Factor Estimation



5. Factor Estimation

In this chapter, we discuss the estimation of the coefficients or factors that impact unlisted infrastructure secondary market prices (computed as price-to-sales ratios) using the dynamic multifactor approach described in chapters 3 and 4.

5.1 Estimating the K Factor Effects

Linear models assume independence between draws of the stochastic process as well as between explanatory variables. However, examination of the raw data reveals several issues in this respect.

First, transaction price ratios are not independent over time but show clear signs of serial correlation.¹¹

Second, correlations between price ratios and candidate explanatory variables are found to be time varying. Table 4 shows the Pearson correlation coefficients¹² of observed PSRs with some of the main expected pricing factors in 10 consecutive time brackets.

Clearly, correlations between the dependent variable (the PSR) and some of its explanatory variables change in magnitude and sign over time. This can be the result of both a time-varying relationship between these variables ($\beta_{k,t}$ changes over time) or the result of a noise in the data due to the observation biases discussed earlier (different types of assets trade at different times in different markets).

For instance, while equation 3.1 suggests a positive relationship between price ratio and profit margin, the correlation between

actual PSRs and profit margin is found to be negative between 2007 and 2012, before it turns negative again in 2015.

Table 2 shows the descriptive statistics for the model's input variables. To the six risk factors discussed in chapter 3, we add individual sector control variables (dummies) for those sectors that constitute the largest groups in the price sample.¹³ The PSR dependent variable and the size, leverage, profit-margin, and term-spread independent variables use a log-transform (indicated by an asterisk).

We first estimate the coefficients for the standard ordinary least square (OLS) regression model described in equation 4.1. Table 3 shows the estimated OLS coefficients and their t-statistics.

The OLS model is static and ignores any time variation of the coefficients. It pools all transaction data together; considers the relationship between each PSR and each of the corresponding, contemporaneous variables; and estimates an average effect for each factor across the whole sample.¹⁴

While the static linear model achieves an adjusted R-squared of approximately 20%, table 3 shows that there is limited statistical significance in such a setting.

The reasons for the poor performance of the static OLS model are the two issues described above: transaction price ratios are not independent in time; and their covariance with explanatory variables is time-varying, partly because of the heterogeneity

11 - The Ljung-Box test, which identifies whether any of a group of autocorrelations of a time series are different from zero, is used, and we can reject the null hypothesis that autocorrelation in the transaction-price data is zero with a very high degree of confidence. The test statistic is 62.966 and the null is rejected with a p-value of 0.000002451.

12 - The Pearson correlation coefficient between two variables x and y is written $\rho_{x,y} = \frac{COV(x,y)}{\sigma_x \sigma_y}$, hence it is a direct proxy of regression coefficients or β s, which are written $\beta = \rho_{x,y} \frac{\sigma_x}{\sigma_y}$.

13 - Not all the sectors represented in the bottom-left pie chart on page 24 have a dummy variable, thus avoiding the usual "dummy trap" issue.

14 - These effects are those that minimise the sum of squared differences between observed PSRs and those predicted by the model.

5. Factor Estimation

of observable transactions over the period and partly because investor preferences can evolve over time.

The relationship between each factor and price ratios is better estimated iteratively in a dynamic fashion using the approach described in chapter 4.

5.2 Dynamic Model

Using the dynamic model in equation 4.3, we estimate each of the K coefficients $\beta_{k,t}$ on each transaction date and report their effect on prices *ceteris paribus*.

By design, Kalman filters aim to separate the signal (systematic effects) from the observation noise (the idiosyncratic component of prices), which is treated as Gaussian white noise (we return to this below).

As discussed in chapter 4, we report *smoothed* coefficient estimates, that is, estimated retrospectively, taking into account all observations until the last available price.

Figures 3 to 5 show the resulting individual factor effects over time (averaged at the end of each month) and their 95% confidence interval. Table 5 shows the mean, median and standard deviation of the time series of each effect.

Since the PSR dependent variable is log-transformed, coefficient estimates can be interpreted as semielasticities (percent change in PSRs for one unit change in raw variables) for untransformed explanatory variables, or

elasticities (percent change in PSRs for 1% change in the logged variable) for log-transformed variables.

We note that not all factor effects are time-varying: a number of fundamental factors and sector control variables have constant estimators for the sample period. We first report the effect of the five fundamental factors before turning to the sector control variables.

1. The **size** effect has the expected negative effect on prices, that is, as a proxy of the inverse of liquidity, larger asset size in unlisted infrastructure impacts required returns positively (and lowers prices correspondingly). Larger stand-alone investments in infrastructure are relatively more illiquid but also complex and characterised by greater information asymmetries between buyers and sellers. Hence, an increase in 10% of the size of the firm (total assets) can be expected to decrease PSRs by approximately 1%, holding other effects constant.
2. **Leverage** also has the expected negative sign on average, even though its 95% confidence interval suggests that this effect cannot be expected in all investments. Higher leverage tends to correspond with lower PSRs. It can be expected to create a limit or even block equity payouts ("lockup") and signals higher business risk. This effect changes over time and has practically disappeared by 2012, at which point it is centred around zero. From 2013 however, the pricing of leverage in unlisted infrastructure transactions returns to a negative sign and

5. Factor Estimation

Table 2: Model Input Data - Descriptive Statistics

Inputs	Mean	Median	Min	Max	StdDev	Obs
Growth Asset	0.257	0.000	0.000	1.000	0.437	680
Price-to-Sales*	1.404	1.304	-0.661	4.087	1.045	680
Airports	0.122	0.000	0.000	1.000	0.328	680
Network Utility	0.126	0.000	0.000	1.000	0.333	680
Oil & Gas	0.085	0.000	0.000	1.000	0.280	680
Ports	0.026	0.000	0.000	1.000	0.161	680
Power	0.056	0.000	0.000	1.000	0.230	680
Renewables	0.185	0.000	0.000	1.000	0.389	680
Roads	0.076	0.000	0.000	1.000	0.266	680
Social Infrastructure	0.221	0.000	0.000	1.000	0.415	680
Leverage*	-0.330	-0.176	-3.512	1.389	0.491	680
Profit Margin*	0.024	-0.009	-1.880	1.949	0.740	680
Rev Growth	0.249	0.046	-0.881	7.743	0.932	680
Size*	5.852	6.041	-1.231	10.914	2.074	680
Term Spread*	0.913	1.153	-0.167	2.286	0.531	680
Value	0.120	0.000	0.000	1.000	0.325	680

* indicates a log-transform.

Table 3: Ordinary Least Square Regression Results

	Estimate	Std Error	T-Value	Pr(> t)
Intercept	1.6424	0.2039	8.05	0.0000
Size*	-0.0922	0.0207	-4.45	0.0000
Leverage*	-0.0997	0.0843	-1.18	0.2377
Profit Margin*	0.1405	0.0580	2.42	0.0157
Term Spread*	0.0073	0.0762	0.10	0.9242
Value	0.2234	0.1324	1.69	0.0919
Rev Growth	0.0005	0.0007	0.68	0.4958
Growth Asset	0.2352	0.1144	2.06	0.0403
Airports	0.0478	0.1647	0.29	0.7716
Network Utility	0.2336	0.1654	1.41	0.1586
Oil & Gas	0.3652	0.1744	2.09	0.0367
Ports	0.2737	0.2935	0.93	0.3514
Power	-0.2261	0.2114	-1.07	0.2853
Renewables	0.7929	0.1570	5.05	0.0000
Roads	0.2009	0.1826	1.10	0.2718
Social Infrastructure	-0.4928	0.1541	-3.20	0.0015

Adj - R² = 20.28%, * indicates a log-transform.

Table 4: Pearson Correlation Coefficients between Key Factors and PSRs over Time

Starting	Ending	Size	Leverage	Term	Profit	Age	Growth	Obs
1995	2005	-0.157	-0.150	-0.003	0.126	-0.176	0.020	68
2005	2007	0.007	-0.248	0.064	0.203	-0.047	0.339	68
2007	2009	-0.041	-0.231	0.110	0.049	0.124	0.246	68
2009	2011	-0.229	-0.059	0.166	-0.052	-0.160	-0.027	68
2011	2012	0.087	-0.121	-0.085	-0.032	-0.096	0.211	68
2012	2013	-0.023	-0.231	0.038	0.524	0.177	0.093	68
2013	2014	-0.096	-0.121	-0.273	0.172	-0.144	0.236	68
2014	2015	-0.413	0.305	0.039	0.154	-0.279	0.271	68
2015	2017	-0.375	-0.064	-0.098	-0.394	-0.296	0.463	68
2017	2018	-0.192	-0.174	-0.235	0.152	-0.222	0.221	68

Size is total assets (log), Profit is the profit margin, Leverage is the ratio of current and noncurrent liabilities to total assets, Term is the difference between the 20-year and the 3-month risk-free rate, Age is the number of years since incorporation, and Growth is the growth rate of revenues.

5. Factor Estimation

also becomes stronger and more significant statistically. By 2018, an increase in leverage of 10% corresponds to a lower PSR by 3.5%.

3. The **profit** effect has the expected positive sign but also changes over time and, as with leverage, there is evidence that this effect had all but disappeared by 2011 before becoming positive again and stronger so that by January 2013 a 10% higher profit margin (after tax) implies a PSR 5% higher *ceteris paribus*. This level of pricing of the profitability of infrastructure companies was short-lived and was, again, indistinguishable from zero by 2017.
4. The effect of the **term spread** has the expected negative sign: an increase in the difference between long- and short-term interest rates can be related to a decrease in the PSR. By 2018, a 10% increase in the term spread can be expected to decrease PSRs by 1% on average. For instance, in 2017, the German term spread is estimated to be 1.32 while the Spanish equivalent is 3.83. Hence, a shift from one country to the other represented an increase in the term spread of 190%, close to a 20% drop in PSR, taking other effects into account.
5. The **value** effect, by which infrastructure investments represent long-term value at the greenfield stage, is found to increase PSR by 26% on average.¹⁵ This highlights the role of the lifecycle in the valuation of infrastructure companies.

6. **Growth** is measured using two effects:
 - *Realised* revenue growth increasingly tends to have the expected positive sign until 2010, but this effect then disappears until 2013. From that point the

effect becomes stronger and systematic (the 95% confidence interval does not include zero) and seems to peak in 2017. In 2018, a 100-basis-point increase in revenue growth should, on average, increase the PSR by 10%.

- Conversely, the *expected* growth effect associated with merchant business models is persistent and has the expected positive sign: merchant infrastructure firms trade at a PSR that is 22% higher than the average.
7. The regression **intercept** captures the level of average prices that is not explained by risk factors or control variables¹⁶ and shows an increase in the mean PSR from 2007 onwards. This can be interpreted as the evolution of aggregate investor preferences, irrespective of systematic risk factors, since unlisted infrastructure equity has become a more sought-after investment over the past decade.

Next, we consider sector effects described in figure 4 and 5. These effects are also *ceteris paribus*, that is, taking into account the effect of the factors described above, including size and leverage. Because these sector effects are categorical they can be interpreted as semielasticities, that is, percentage change in PSR relative to the predicted mean.

1. **Airports** show an increasing price trend over the period, from a negative effect (lower PSRs) until 2007, to a positive but limited premium until 2013, after which the valuation of airports goes through another step change until 2016. By then, unlisted airport companies are 49% more expensive on average than the

¹⁵ - The variable is categorical, and the interpretation of the coefficient for a log-level model is a semielasticity.

¹⁶ - The intercept of the model represents the average expected price ratio when all other variables are equal to zero and can be difficult to interpret directly. Continuous variables are log-transformed, hence they have a value of zero when the nontransformed variables equal unity, for example, an investment of 1 million dollars with 100% profit margin and leverage, etc. The level of the intercept is thus not relevant on its own.

5. Factor Estimation

population mean. This effect appears to have stabilised, and the confidence interval of the coefficient suggests that very few individual airports do not have a positive price premium by 2018.

2. **Network utilities** are priced consistently 28% above the average PSR, reflecting the expected stability of earnings and payouts.
3. **Oil & gas** companies and projects are priced even higher at a persistent 42% above the average PSR, potentially reflecting stronger growth expectations.
4. **Ports** however, while they also exhibit an above-average PSR (30%), see a lot of price variability, including below the sample average for a significant portion of companies. In terms of systematic effects, it is not obvious what distinguishes port companies from the average of the sample.
5. Conventional power projects have an average PSR that is consistently 14% below the average, but again the variance of this effect, illustrated by the 95% confidence interval, is such that power companies can be said to be mostly impacted by the fundamental factors described earlier and not so much by a sector-specific effect.
6. Conversely, **renewable-energy** projects have the highest and most consistently positive PSR level, peaking at 80% in 2013 and decreasing to 68% above the sample average in 2018. This effect varies but is always positive and highly significant. This highlights the belief by many investors in the future demand for renewable energy (which is also a hedge for conventional power). Since 2013, less generous regulatory support mechanisms

and subsidies may have contributed to decreasing the average PSR in this sector.

7. **Roads** in general exhibit a positive but not systematic tendency to have higher PSRs than the average (30%). This average effect, however, disappears in 2013–15, during which numerous road projects were faced with defaults and bankruptcy in Europe and Australia. Since then however, the tendency to price road projects above the average PSR has returned and is stronger than before, at 42% above the average PSR and a more significant positive effect statistically.
8. **Social infrastructure**, with its fixed output specification and contracted revenue stream is probably the sector with the least potential for revenue growth. Compared to the average PSR, price levels in this sector are significantly below average (on average 42%).

We return to these effects and their interpretation in chapter 6. Next, we discuss the statistical robustness of these findings.

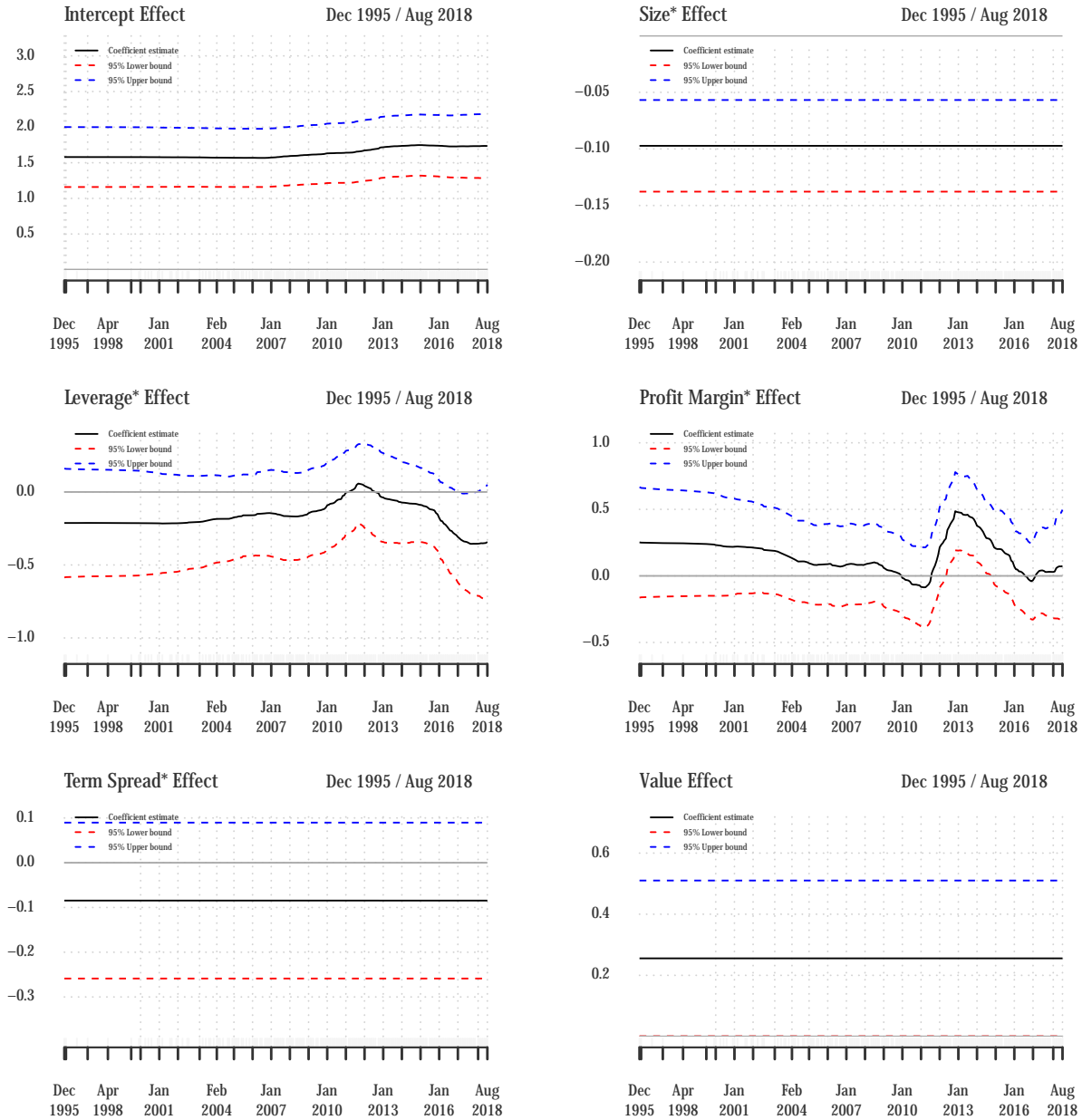
5.3 Robustness

The multifactor model in equation 4.2, represents the combination of each factor's individual and independent effect on *average* transaction prices and treats the idiosyncratic component of transaction prices as white noise, V_t .

The primary robustness check is to see whether the model's residuals are indeed white noise, that is, distributed according to a Gaussian process. Key test statistics of the

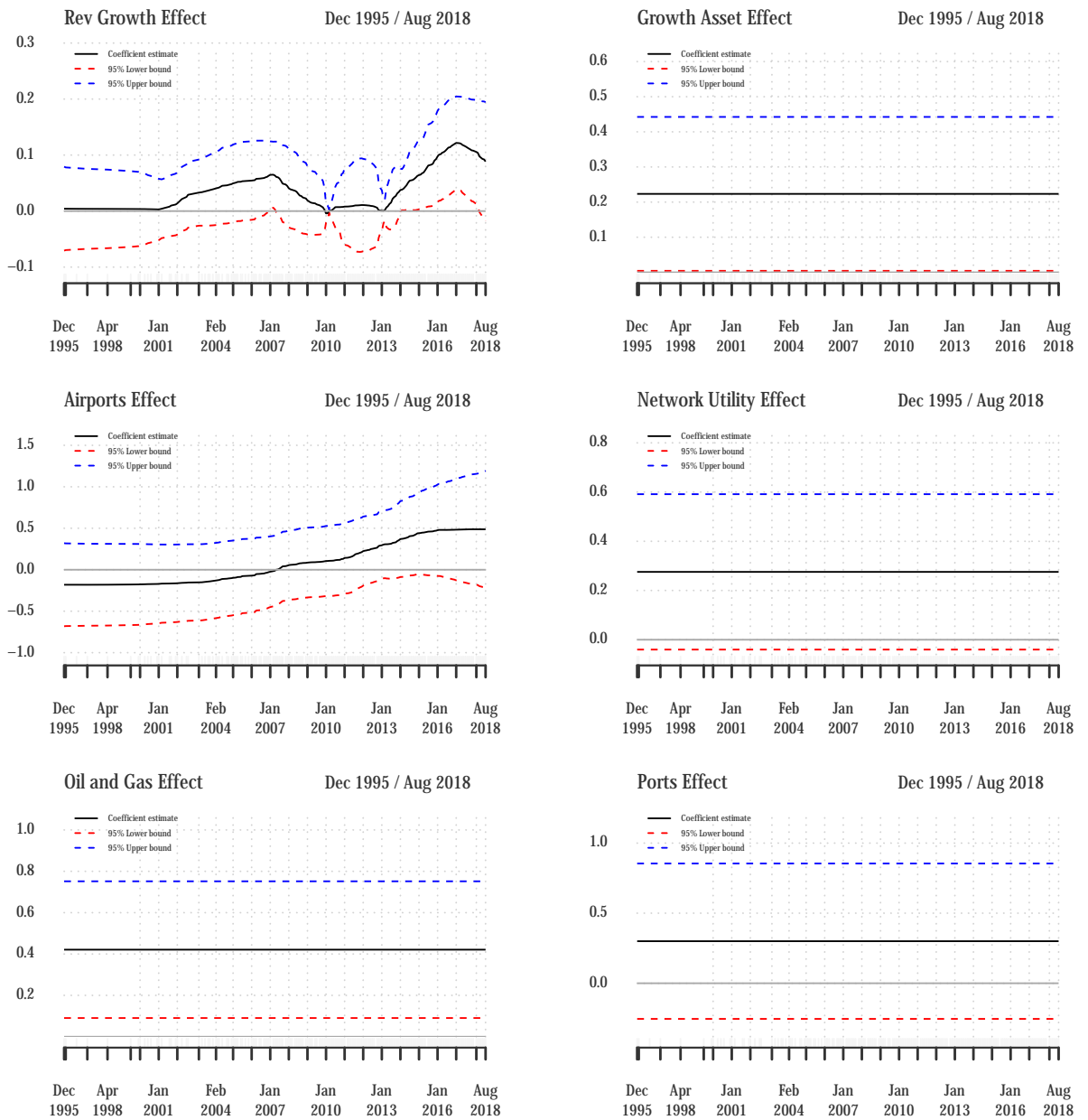
5. Factor Estimation

Figure 3: Smoothed Time-Varying Effects on Price-to-Sales



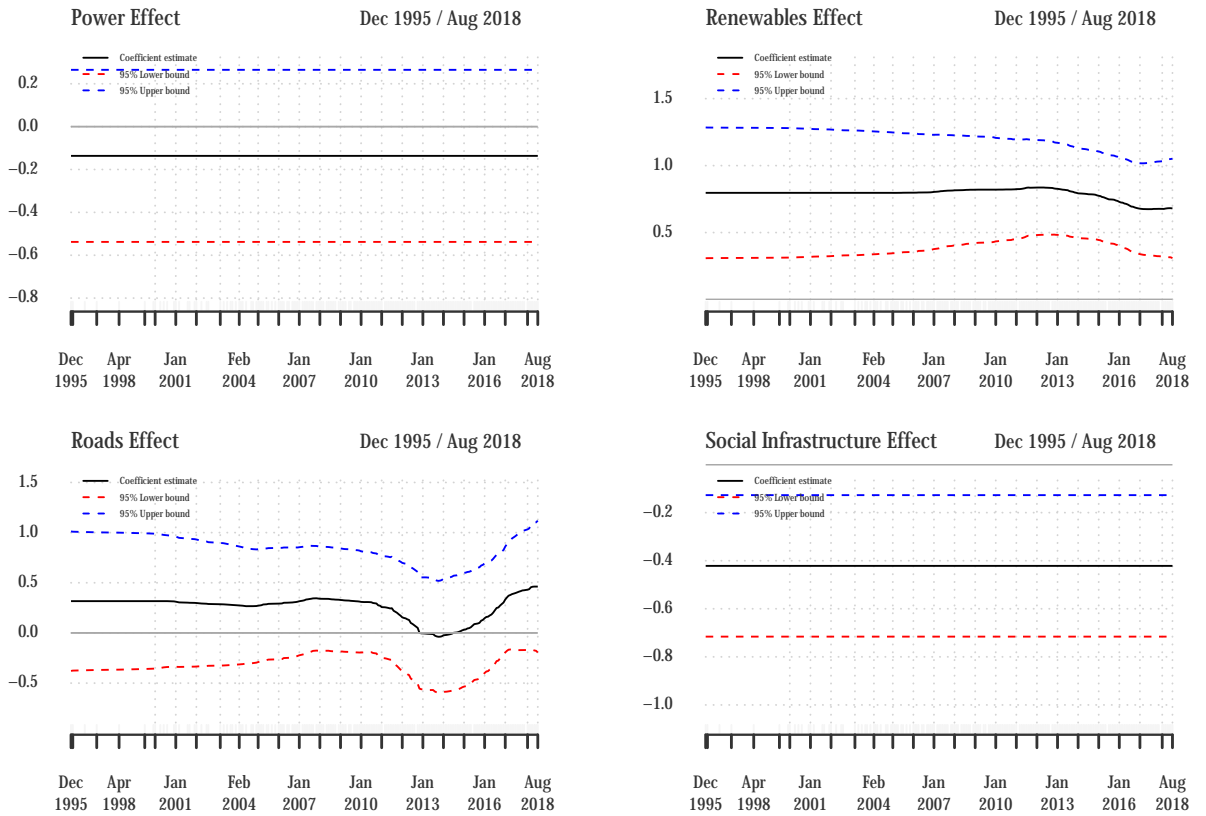
5. Factor Estimation

Figure 4: Smoothed Time-Varying Effects on Price-to-Sales



5. Factor Estimation

Figure 5: Smoothed Time-Varying Effects on Price-to-Sales



5. Factor Estimation

Table 5: Descriptive Statistics of Time-Varying Coefficients

	Min	Max	Median	Mean	StdDev
Size*	-0.10	-0.10	-0.10	-0.10	0.00
Leverage*	-0.35	0.03	-0.17	-0.16	0.09
Profit Margin*	-0.07	0.45	0.10	0.15	0.14
Term Spread*	-0.08	-0.08	-0.08	-0.08	0.00
Value	0.26	0.26	0.26	0.26	0.00
Rev Growth	-0.00	0.12	0.03	0.04	0.04
Growth Asset	0.22	0.22	0.22	0.22	0.00
Airports	-0.18	0.49	0.05	0.09	0.25
Network Utility	0.28	0.28	0.28	0.28	0.00
Oil & Gas	0.42	0.42	0.42	0.42	0.00
Ports	0.30	0.30	0.30	0.30	0.00
Power	-0.14	-0.14	-0.14	-0.14	0.00
Renewables	0.68	0.83	0.80	0.79	0.04
Roads	-0.02	0.42	0.29	0.25	0.12
Social Infrastructure	-0.42	-0.42	-0.42	-0.42	0.00

Table 6: Goodness-of-Fit Statistics

	Filtered	Smoothed
MSE	2.04	0.70
ME	0.01	0.00
MedE	-0.03	-0.07
MAD	0.83	0.65
MedAD	0.56	0.52

ME: mean error, MedE: median error, MSE: mean squared error, MAD: mean absolute deviation, MedAd: median absolute deviation

normality of residuals are reported in table 14 in the appendix.

Overall the residuals can indeed be considered to be distributed according to a Gaussian process, even though a few points are outside the equivalent normal process, as shown in figures 6 and 22 (appendix)

Regression residuals pass the Kolmogorov-Smirnov test quantifying the distance between the empirical distribution function of the sample and the cumulative distribution function of a reference Gaussian distribution.¹⁷

The residuals are also uncorrelated and pass the Ljung-Box test, which asks whether any of a group of autocorrelations in a time series are different from zero. As for the null

hypothesis of normality, we cannot reject the null hypothesis that autocorrelation in the residuals is zero. Test statistics for autocorrelation and normality are reported in table 14 in the appendix.

The absence of correlation in the residuals validates the hypothesis of conditional independence of the price observations made in chapter 4: conditional on the state $\theta_{1:t} = [\beta_{1,1:t} \dots \beta_{K,1:t}]$, transaction prices $Y_{1:t}$ are independent in time.

We also report variance inflated factors (VIF) of less than 1.5, signaling the absence of significant multicollinearity in the model's variables, that is, the model's explanatory variables are reasonably uncorrelated. Their correlation plot can be seen in the appendix in figure 21.

17 - The null hypothesis that the sample is drawn from the reference distribution.

5. Factor Estimation

With reasonably Gaussian and uncorrelated residuals, our coefficient estimates can be considered unbiased and robust.

A final robustness test consists of comparing the filtered PSR in the last step of the Kalman filter at each point in time with the actual observed transaction price at that time. Table 6 reports mean and median error and mean and median absolute errors.

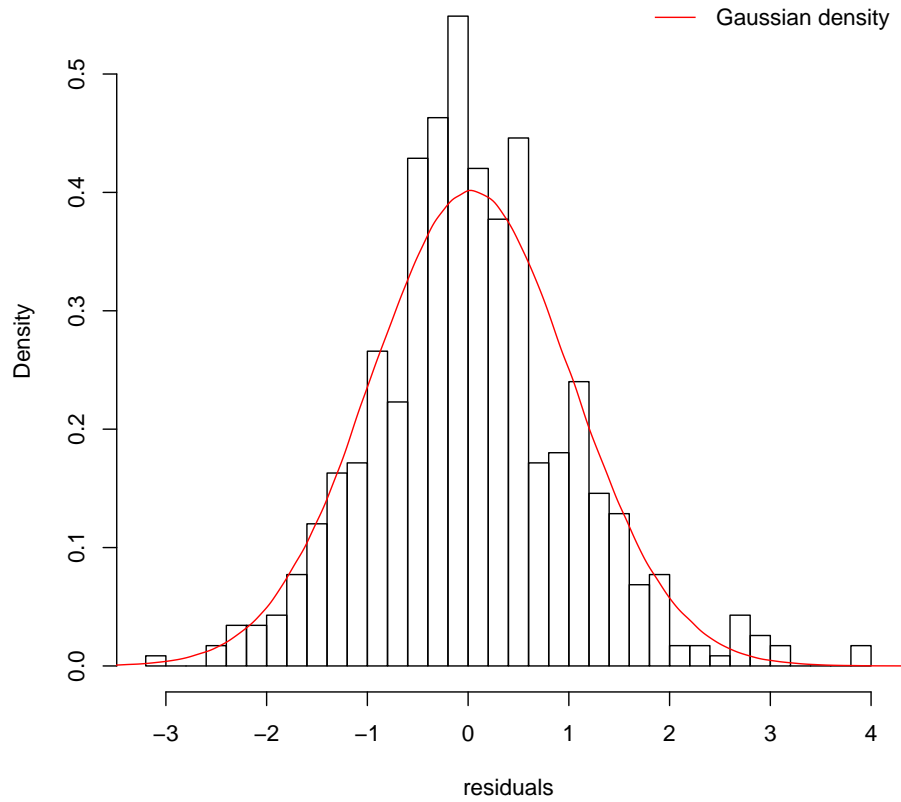
As argued above, a factor model predicts the systematic effects of various explanatory variables on average prices. Hence, it cannot predict the idiosyncratic part of individual prices. In private, illiquid, and opaque markets (with no shorts) such as unlisted infrastructure, it is unsurprising that individual valuations should vary a lot from one buyer to the next, even for similar assets exposed to the same risk factors with the same loadings and in comparable market conditions.

As a result, *absolute* median and mean errors reported are large. However, the mean and median errors, in line with the robustness of the model coefficients, are very low between -3 and 7% . The mean error of the smoothed effect model, which is the one reported above, is not different from zero. In other words, while the model does not predict individual transaction prices with great accuracy, it does capture the determinants of average transaction prices quite well.

Using these results, we report market-level average price ratios using estimated coefficients in chapter 6.

5. Factor Estimation

Figure 6: Dynamic Linear Model Residuals and Equivalent Gaussian Density



6. Market Trends



6. Market Trends

In this chapter, we report unlisted infrastructure market trends by applying the factor model estimated in chapter 5 to the much larger and representative sample of firms present in the EDHEC*infra* universe and described in chapter 3.

For each of the 600+ firms present in this universe, we estimate a *shadow price* determined by the time-varying factors described in the previous chapter and each firm's own factor loading, that is, size, leverage, profitability, control variables, etc. We can estimate this shadow price every time these firms report their factor loading (typically once a year) using the time-varying factor effects that we documented in chapter 5.

We estimate approximately 6,000+ shadow prices over the 1998–2017 period. Using shadow PSRs, we also derive each firm's price-to-earnings ratios (PERs). In what follows, we report average PSRs and PERs for the broad market and individual sector and country segments and compare these results with average PSRs and PERs for the S&P500 index.

6.1 Broad Market

The unlisted infrastructure equity broad market PSR is computed in the same manner as the S&P500 PSR. Following Standard and Poor's (2018), we have:

$$PSR_{S\&P500,t} = \frac{\sum_i \text{index market capitalisation}_t}{\sum_i \text{Total Revenues}_t}$$

for all stocks i . Hence,

$$PSR_{infra,t} = \frac{\sum_j \text{Equity Prices}_t}{\sum_j \text{Total Revenues}_t}$$

for all unlisted infrastructure companies j .

This formula of the broad market PSR takes the weight of individual companies into account. As a result, it is lower than the plain average of individual PSRs, since larger firms tend to have lower PSRs, as we reported in the previous chapter.

Figure 7 shows the $PSR_{S\&P500,t}$ and $PSR_{infra,t}$ for the 2000–2017 period. We note that PSRs are noticeably higher for unlisted infrastructure assets than they are for public equities, irrespective of market conditions. As discussed earlier, PSRs should reflect the willingness to pay for future risky revenue growth and dividends, adjusted for risk.

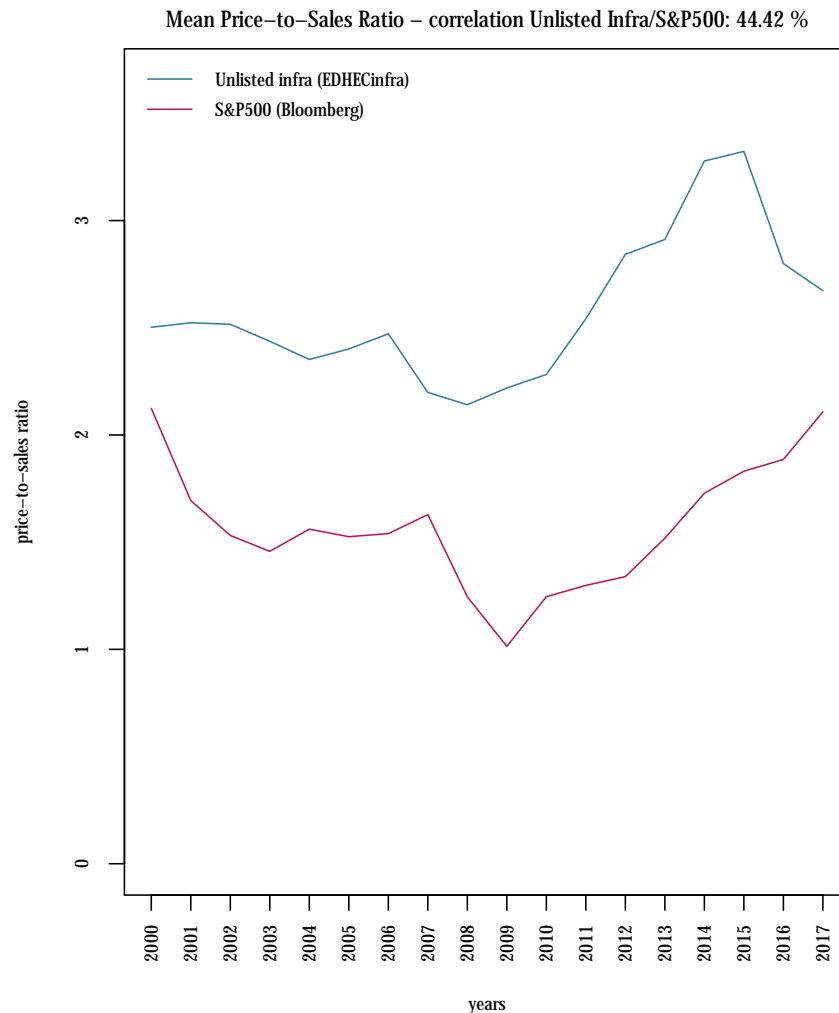
It has been documented in previous research (see Blanc-Brude et al., 2016) that the dividend payout ratios of unlisted infrastructure firms are significantly higher (20% of revenues paid out as dividends on average 10 years after the firm's creation) than comparable listed equity payout ratios, which are more stable (cf. the so-called "sticky dividends" theory) but much lower and average 3–5% of revenues.

Hence, each dollar of equity value invested in infrastructure companies can be expected to generate a much greater amount of dividends per dollar of future sales. As a result, the median PSR for the unlisted infrastructure sector should be significantly higher than that of the S&P500.

We also note that the two measures, while not completely correlated, exhibit a degree of comovement over time, with a Pearson correlation of 45% over the 2000–2017 period.

6. Market Trends

Figure 7: Mean Unlisted Infrastructure and S&P500 Price-to-Sales Ratio



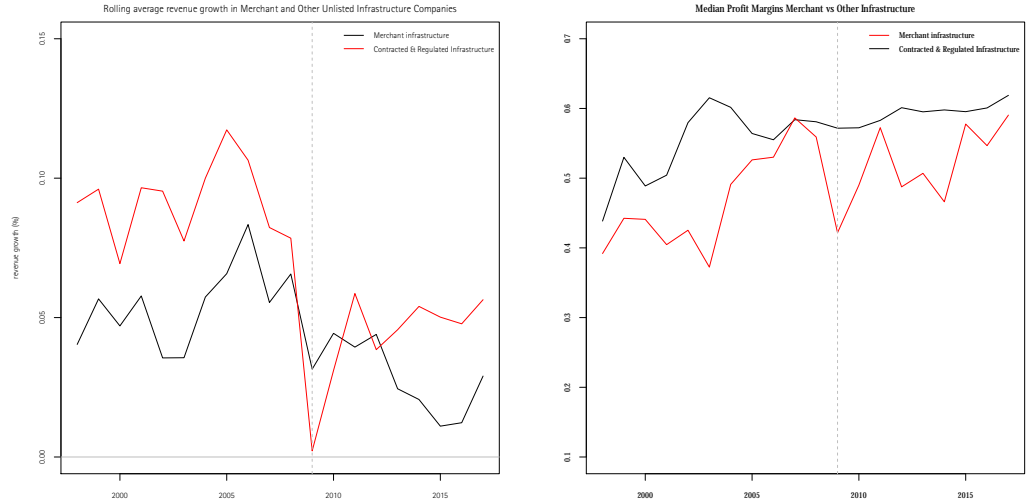
This comovement is explained by the dynamics of the unlisted infrastructure PSR. For instance, looking at the raw revenue data from 2008, we see that unlisted infrastructure companies experienced a sharp drop in revenue – especially the merchant companies in the port, airport, and power sectors, which, at the aggregate level, experienced negative revenue growth in 2008, as shown on figure 8. At the same time, average estimated PSRs also decrease, that is, the denominator of the PSR decreased (as shown on figure 7),

but aggregate prices decreased more than proportionally.

From 2011, the dynamic changes: average revenue growth weakens for nonmerchant infrastructure firms, notably network utilities and social infrastructure, whereas aggregate merchant infrastructure revenue growth bounces back to a stable but lower aggregate level due to decreasing revenue growth in the port and power sectors (revenue growth is

6. Market Trends

Figure 8: Median Revenue Growth and Profit Margins for Merchant and Other Unlisted Infrastructure



Revenues include financial revenues.

negative in the power sector between 2013 and 2016).

Yet, in aggregate, prices increased over that period, as evidenced by the PSR: in a stable or even declining revenue-growth environment, average PSRs increased considerably until 2015. This corresponds to the period during which the *revenue growth* factor effect is essentially equal to zero on average, as reported in chapter 5. In other words, during that period revenue growth and the pricing of unlisted infrastructure companies became uncorrelated, contradicting theory.

Unlisted infrastructure then appears to have reached a PSR peak. In the most recent period of 2016-17, revenue growth increases again. Prices however have plateaued, as evidenced by the decrease in the median PSR.

Next, figure 9 compares the unlisted infrastructure market PER with that of the S&P500. As for the PSR, this ratio is computed using

the S&P methodology, by dividing the sum of prices by the sum of earnings (profit after tax) in each period. Firms reporting negative earnings are included.

Formally, PERs are written:

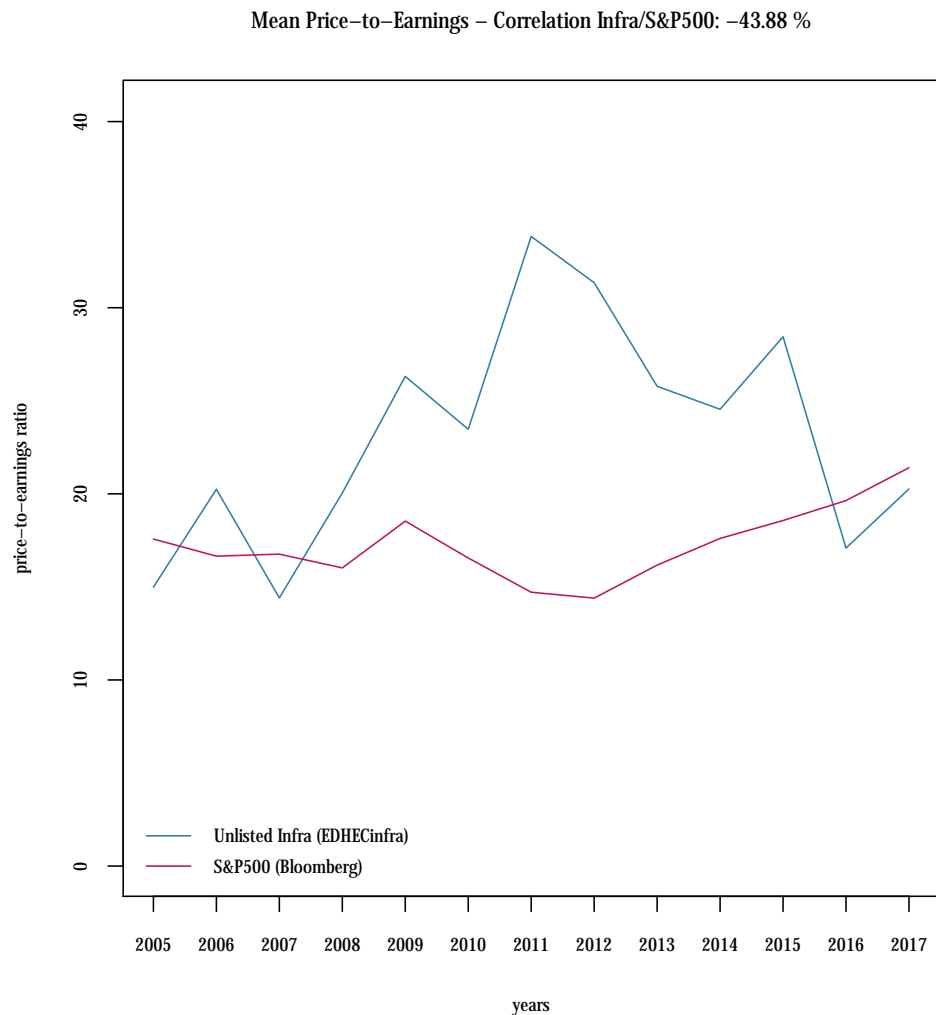
$$PER = \frac{E(\text{Payout Ratio})}{r - g}$$

Hence, since unlisted infrastructure tend to have higher payout ratios as well as lower expected revenue growth than public equities, they should tend to have higher PERs than stocks as long as investors' expected returns are not too high.

We note that unlisted infrastructure PERs truly become higher than the S&P500's after 2008. During the 2008-2009 period, aggregate unlisted infrastructure prices are in fact decreasing, as discussed above, but aggregate earnings are decreasing more rapidly, especially in the port and airport sectors, hence, average PERs increase.

6. Market Trends

Figure 9: Mean Unlisted Infrastructure and S&P500 Price-to-Earnings Ratio



In 2010, aggregate earnings recover, including in ports and airports, but they fall again in 2011 because of large drops in earnings in the primarily merchant road sector. From 2012 however, aggregate earnings increase rapidly until 2014 (despite a drop in the power and renewables sectors), leading to lower average PERs.

Aggregate earnings drop again in 2015, primarily in the oil and gas, network utilities, and power sectors, before recovering

somewhat in 2016. They fall again in 2017, especially in the port and power sectors.

This see-saw movement of aggregate unlisted infrastructure earnings, which creates equivalent swings in the average PER, is due to the combination of financial and operational leverage typically found in infrastructure companies: profits are quite sensitive to variations in revenues and, as the result, PERs are quite volatile.

6. Market Trends

The fact that the volatility of the PER is primarily due to the volatility of earnings also shows that prices did not respond very much to short-term changes in financial conditions during that period.

Hence, the 2011 peak and 2015 PER peaks correspond to periods of prices rising while earnings were falling. Still, after the 2015 peak, prices level-off (as implied by the PSR level), and this could be considered to mark the end of the rapid rise in valuations of unlisted infrastructure equity that broadly characterised the post-GFC period.

6.2 Sector Trends

Figures 10 and 11 show PSR trends by sectors using the S&P500 index PSR as a point of reference. Table 7 also provides a summary of PSRs and PERs by sector for the whole period. Note that unlike the ratios reported in figures 7 and 9, which are computed to be comparable with the S&P500 equivalent, table 7 reports median company-level PSR and PER.

In line with the results reported in chapter 5, we see that there is a range of price-to-sales and price-to-earnings ratios depending on the infrastructure sector. At the bottom of the scale, with median PSR below 3, social infrastructure and waste stand out as low-growth, low-risk sectors, with correspondingly higher median PER in the 15-25 range. Indeed, social infrastructure and waste-treatment plants are typically designed to deliver a fixed capacity on a stand-alone, contracted basis.

In contrast, power companies have the lowest PSR (1.9) as well as a low PER of (10.1), signaling a higher risk profile. Power generation is constrained in terms of revenue growth by design (generation capacity) and firms often include some merchant aspect in their business model or a mismatch between payback horizon and offtake contract maturity.

Network utilities and telecom companies exhibit a medium-growth (PSR of 2.7 and 2.9), medium-risk (PER of 11.9 and 13.2) profile. These businesses usually exhibit some capacity for growth (network expansion) and benefit from steady income streams due to the partly or completely monopolistic nature of their business model, which is often regulated.

Companies with PSR between 3 and 5 include airports (3.3), roads (3.15), downstream oil and gas projects (3.46), rail (3.5), and ports (3.7). These firms are more likely to experience substantial revenue growth and can be split into two profiles: higher-growth/higher-risk profiles for rail, roads and oil and gas projects, which have PERs in the 8 to 13 range, and higher-growth/lower-risk profiles for airports and ports, which have median PER in the 14 to 15.5 range.

Most road companies collect tolls and are exposed to the economic cycle. On average, roads also exhibit one of the highest levels of financial leverage (defined as the ratio of current and noncurrent liabilities to total assets) in the sample. Likewise, oil and gas companies can be considered riskier, either because they are directly

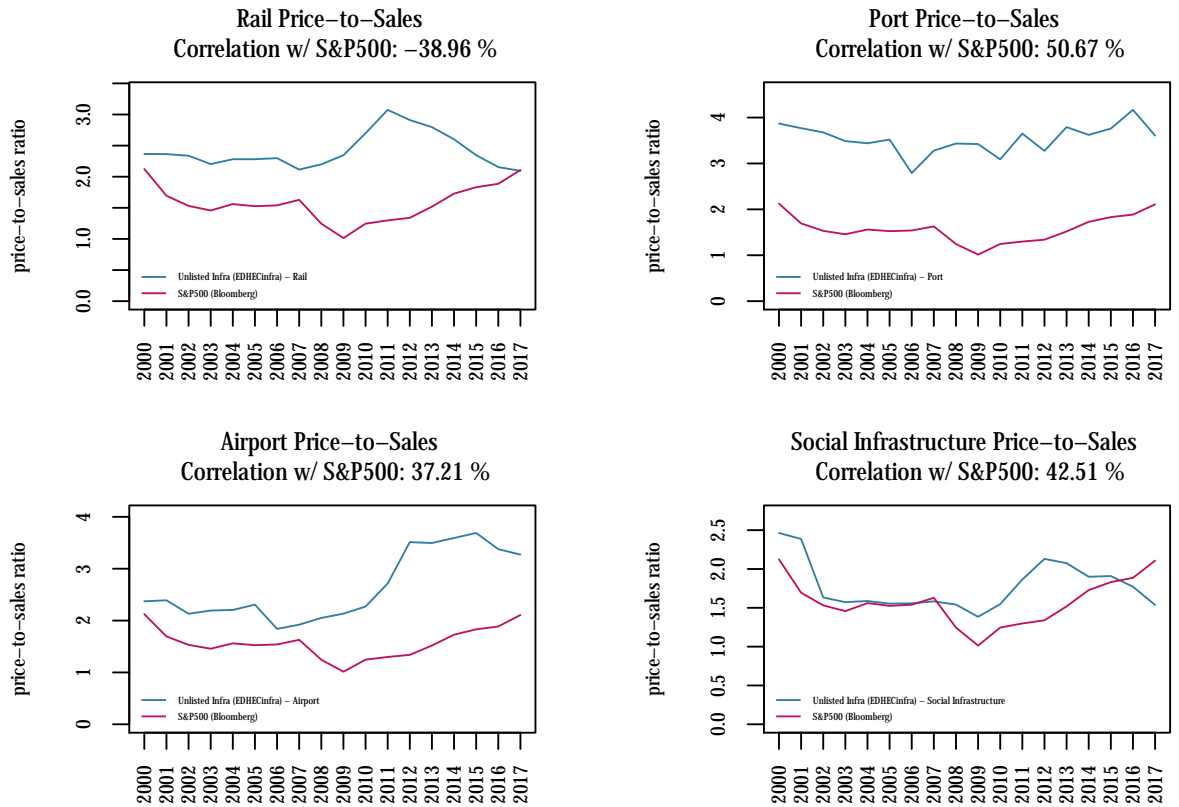
6. Market Trends

Figure 10: Mean Unlisted Infrastructure and S&P500 Price-to-Sales Ratio by Sector



6. Market Trends

Figure 11: Mean Unlisted Infrastructure and S&P500 Price-to-Sales Ratio by Sector (Continued)



6. Market Trends

Table 7: Median Company-Level Price Ratios and Leverage by Sector, 2005-2017

Sector Name	Price-to-Sales	Price-to-Earnings	Leverage	n
Power	1.98	10.14	0.75	1196
Social Infrastructure	2.18	17.13	0.97	642
Network Utilities	2.77	11.91	0.76	898
Telecom	2.95	13.23	0.76	46
Waste	2.99	24.17	0.77	80
Road	3.15	8.21	0.86	1382
Airport	3.30	15.38	0.72	459
Oil & Gas	3.46	10.16	0.74	449
Rail	3.52	12.65	0.89	232
Port	3.65	13.86	0.54	247
Renewables	7.17	20.85	0.85	611

n is the number of observations.

exposed to commodity prices or because commodity price risk creates substantial offtake/counterparty risk in their business.

Conversely, airports and ports are mainly exposed to global and regional trade flows, which have grown steadily and universally over the past two decades. But while high levels of global throughput have been achieved, increased competition in both port and airport sectors, as well as the development of very large "transport hubs," suggests that not all companies can experience significant revenue growth. Still, these firms exhibit lower levels of leverage than other sectors and are priced at the lower end of the risk spectrum.

Finally, renewable-energy companies exhibit a much higher average PSR, above 7, as well as the highest median PER, close to 21. Investors have been willing to pay much more per dollar of revenue and profit in this sector than in any other infrastructure sector. This reflects the degree of confidence with which the future of these investments is perceived. Demand for renewable energy sources has increased steadily over the past decade as has public support for these investments, even though

policies have been reversed or partially phased in a number of jurisdiction.

This level of valuation of renewable-energy companies¹⁸ can seem surprising. Solar or wind farms typically have long-term purchasing contracts in place as well capacity constraints by design (even though these may be upgraded by installing more powerful technology on the same site). Neither can the higher price of these investments be solely driven by lower required returns, since social-infrastructure projects can be considered to have at least equally secure sources of future revenues yet have a lower average PER.

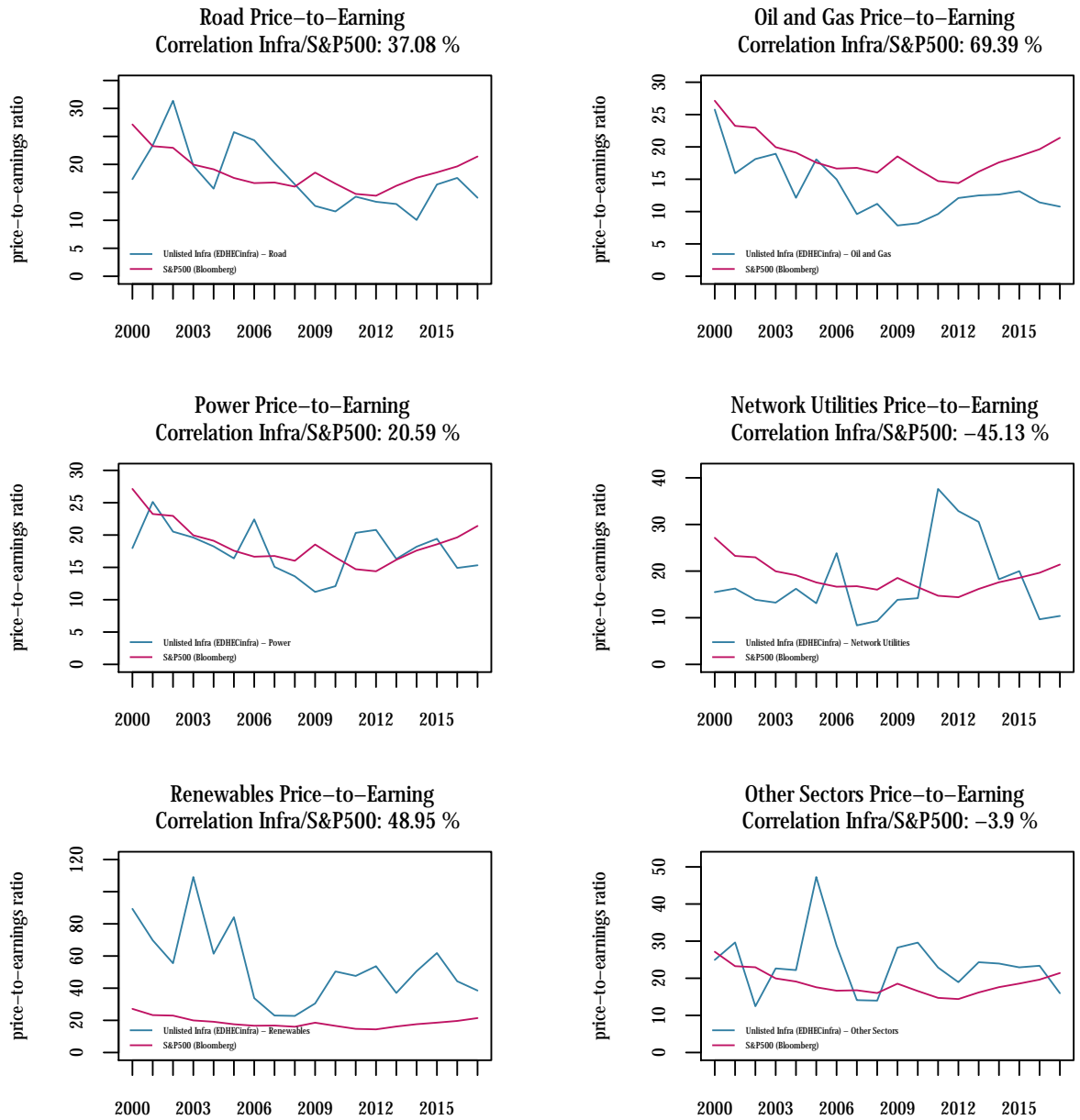
Turning to figures 10, 11, 12, and 13, we see that sector-level pricing dynamics have been significant over the sample period. This provides additional insights:

1. **Roads'** PSR track the S&P500 equivalent quite closely (correlation of 60%). While road PSRs remain high above the public-equity equivalent, road PERs are lower than stocks' and also fairly correlated (40%), for the reasons highlighted above. While road PSRs dipped in 2009, in sync with equities,

18 - Which remains the case using multiple model specifications.

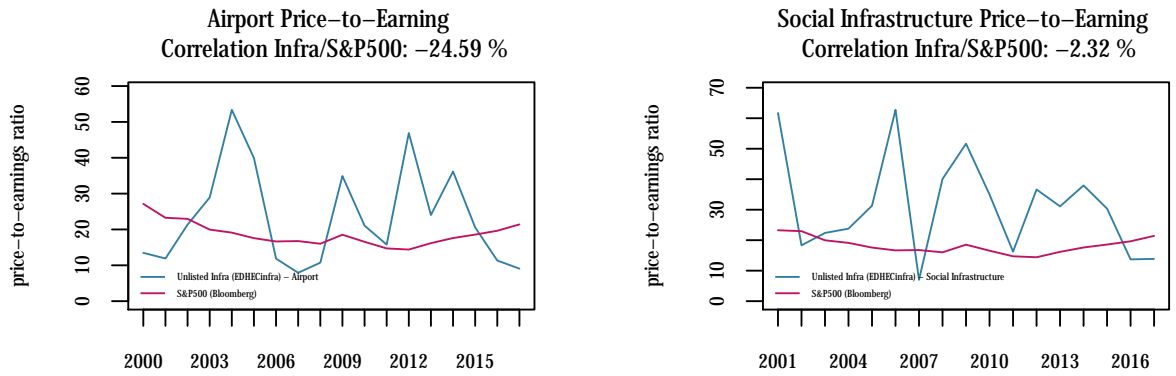
6. Market Trends

Figure 12: Mean Unlisted Infrastructure and S&P500 Price-to-Earnings Ratio by Sector



6. Market Trends

Figure 13: Mean Unlisted Infrastructure and S&P500 Price-to-Earnings Ratio by Sector



6. Market Trends

they also recovered, whereas road PERs have been below equities after 2008.

2. **Oil and gas** PSR are less correlated with equities, but PERs exhibit a 70% correlation, which is stronger in bad times. The high PSR levels of the sector were achieved by 2012 and that pricing has been downtrending, while PERs remain almost flat and below equities.
3. **Power** projects also saw a very rapid increase in PSR from a lower historical base until 2015, after which power PSRs decreased substantially. At that time of price increases, revenues and profits were decreasing in the power sector and there appears to have been a short-lived interest in power generation, which reversed after 2015. With 40% correlation with equities PSRs, power companies are not as exposed to the macroeconomic cycle as roads and oil and gas companies. Fluctuations in earnings over the period can be explained by changes in the regulation of power markets and the growing influence of renewable energy.
4. **Network utilities** have had a high PSR across the period and significant fluctuations in PERs.
5. **Renewables** exhibit a high and stable PSR pattern across time, with drops in 2008-11 and from 2015 but otherwise no apparent correlation with equities. PERs on the other hand are quite correlated and more volatile. This is due to the higher proportion of younger firms in this sector, many of which report negative earnings initially.
6. **Airport** PSRs exhibit rapid growth until 2012 and then stay at a relatively high level

until they begin to decline in 2015, while PERs are found to be quite volatile. While airport do not exhibit the highest levels of financial leverage, as discussed above, they have significant "operational leverage" (i.e., fixed production costs) which makes their earnings very sensitive to small changes in revenues

7. **Social infrastructure** exhibits a PSR level roughly on par with equities but also declining after 2012 while PER levels appear to be extremely volatile.

Overall, we note that a number of sectors have experienced a compression of PSR in the past three to five years following rapid growth after 2008. by 2017, PSR growth seems to have abated across the board in unlisted infrastructure.

6.3 Country Trends

Most countries reached a PSR peak in 2013 to 2015, while others (like Germany or Portugal) have experienced a longer decline. In the appendix, table 15, figures 23, and 24 compare the PSR and PER for those countries for which at least 100 individual results are available. Other markets are aggregated as "other countries."

6.4 Analytics

Finally, we look at the reported valuations by slicing and dicing the results along a number of dimensions of the firm's financials. It should be noted that, contrary to the regression coefficients reported in chapter 5, these results are not stand-alone effects

6. Market Trends

reported *ceteris paribus*, but incorporate all the factor effects described earlier.

Looking at the relationship between size and prices shown in table 8 and figure 14, we see that, consistent with regression results, there is a strong negative relationship between size, PSRs, and PERs. This highlights the sizable effect of larger, more complex, and more illiquid investments on discount rates. We can also see from table 8, which shows median PSRs and PERs across 10 size buckets, that this effect is independent of leverage. Each bucket has median leverage of approximately 80%.

We also note a kink in the PER/size relationship for the last size decile (companies over 2 billion dollars in total assets) suggesting that these very large projects are also characterised by relatively lower earnings.

Next, the relationship between prices and leverage is shown in figure 15 and table 9. The impact of credit risk on valuation is in line with the literature and theory discussed above: low leverage tends to correspond to higher prices (lower discount rates, higher payout ratios).

Between 80 and 100% senior leverage, while PSR tends to keep decreasing, on a PER basis, valuations increase, corresponding to those highly leveraged infrastructure projects with long-term contracted revenues (typically social-infrastructure projects), which have low growth options but are also lower risk, justifying the high leverage and higher valuation of future earnings.

Beyond 100% leverage we find two types of firms: Those just above 100% leverage are in distress or nearing bankruptcy and their PER is negative and very low. Higher levels of leverage corresponds to the *value* firms that also report negative equity. In this segment, PSRs are high, corresponding to the willingness to pay higher prices per dollar of revenue when infrastructure projects are in their initial development phase. PERs stay very low and negative for greenfield projects: as argued above, these are "value" companies.

Figure 16 confirms that *value* infrastructure companies (defined as reporting negative equity and having been incorporated for 10 years or less) report higher PSRs and negative PERs and that the reverse is true for *mature* infrastructure firms.

Next, table 10 and figure 17 report the relationship between unlisted infrastructure companies' age and their price ratios. Again, we see that in their early years, infrastructure firms have lower PERs, increasing with maturity.

We know that the early or "greenfield" development phase attracts higher prices per dollar or revenues because of expected revenue growth but also that leverage lowers PSRs. At the greenfield stage, infrastructure companies are highly leveraged, and these effects offset each other: the resulting PSR is independent of age, taking the other effect into account. It only trends up for firms older than 20 years, which tend to be the growth assets mentioned earlier: airports and utilities.

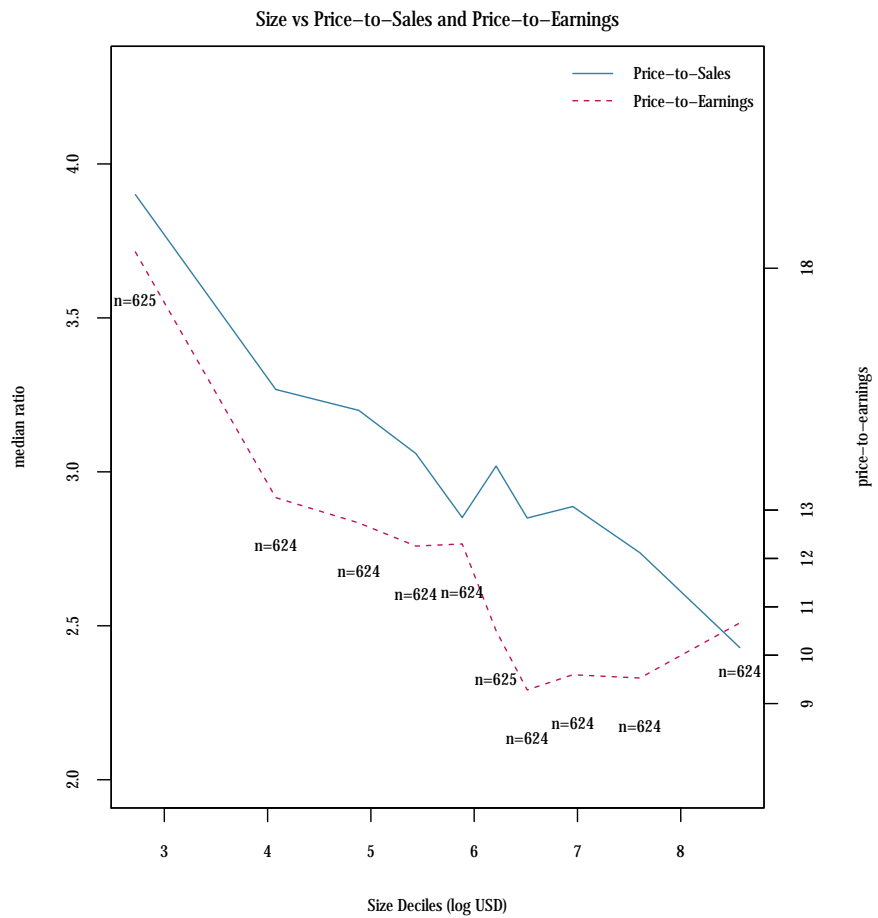
6. Market Trends

Table 8: Median Price Ratios and Leverage by Size Deciles

Median Size (USDm)	Price-to-Sales	Price-to-Earnings	Leverage	n
15.18	3.90	18.34	0.79	625
59.10	3.27	13.26	0.86	624
132.09	3.20	12.73	0.79	624
229.49	3.06	12.26	0.81	624
359.22	2.85	12.30	0.87	624
498.84	3.02	10.51	0.81	625
674.12	2.85	9.28	0.84	624
1048.23	2.89	9.60	0.84	624
2007.97	2.74	9.53	0.79	624
5281.02	2.43	10.67	0.75	624

n is the number of observations.

Figure 14: Price-to-Sales and Price-to-Earnings Ratios by Size Deciles



6. Market Trends

Table 9: Median Price Ratios by Leverage Deciles

Median Leverage	Price-to-Sales	Price-to-Earnings	n
0.30	3.44	15.11	625
0.51	3.12	12.65	624
0.63	3.02	11.11	624
0.72	2.85	13.60	624
0.78	2.89	11.59	624
0.84	2.85	12.37	624
0.90	2.85	12.58	624
0.95	2.71	14.58	624
1.01	2.75	6.05	624
1.21	3.09	-3.23	624

n is the number of observations.

Figure 15: Price-to-Sales and Price-to-Earnings Ratios by Leverage Deciles

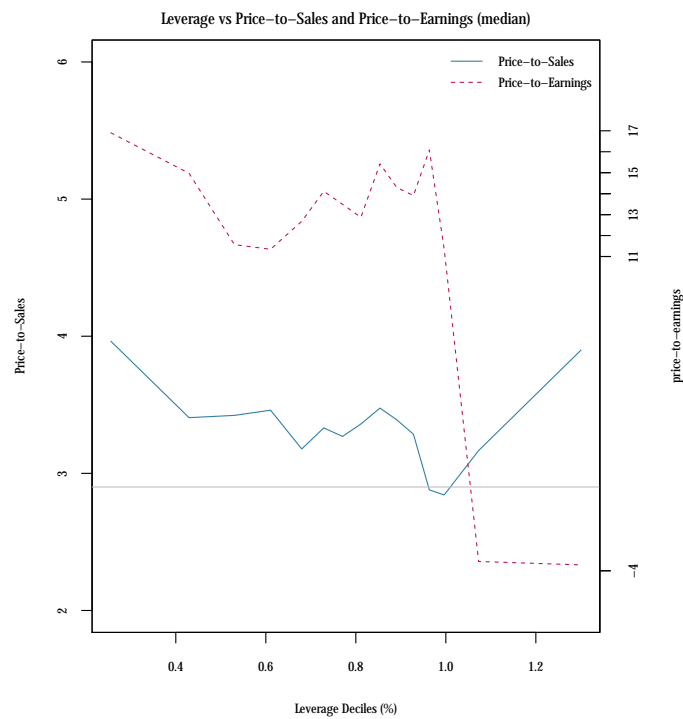


Table 10: Median Price Ratios and Leverage by Age Deciles

Median Age	Price-to-Sales	Price-to-Earnings	Leverage	n
3.00	3.09	6.39	0.88	625
5.00	2.87	11.35	0.89	624
7.00	2.87	12.56	0.88	624
9.00	2.99	13.36	0.86	624
11.00	2.80	11.61	0.83	624
12.00	2.94	12.24	0.81	625
14.00	2.97	13.25	0.80	624
16.00	3.04	12.21	0.74	624
19.00	2.96	10.91	0.73	624
26.00	2.95	11.44	0.69	624

n is the number of observations.

6. Market Trends

Figure 16: Price-to-Sales and Price-to-Earnings Ratios for "Value" Firms

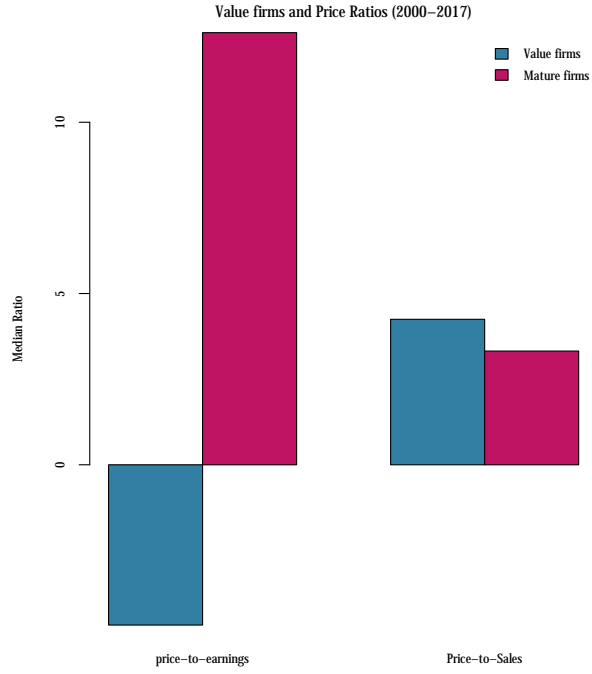
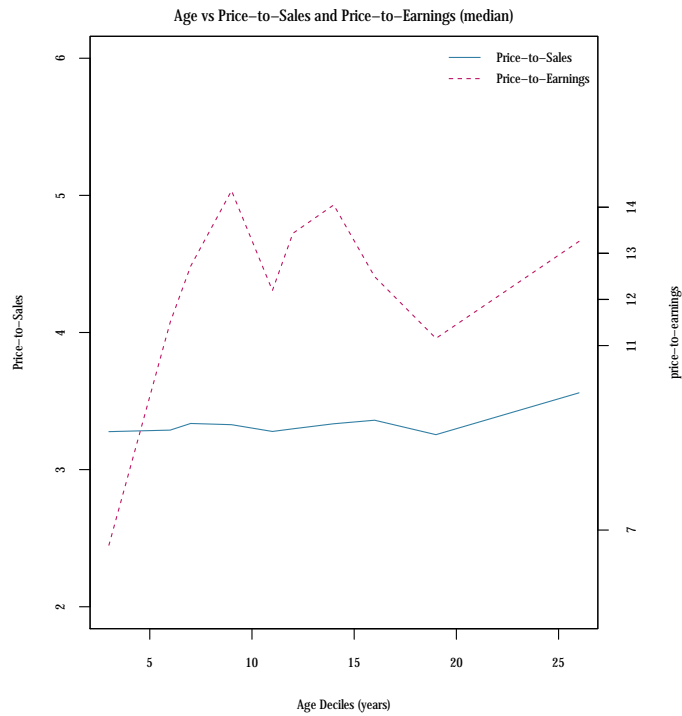


Figure 17: Price-to-Sales and Price-to-Earnings Ratios by Age Deciles



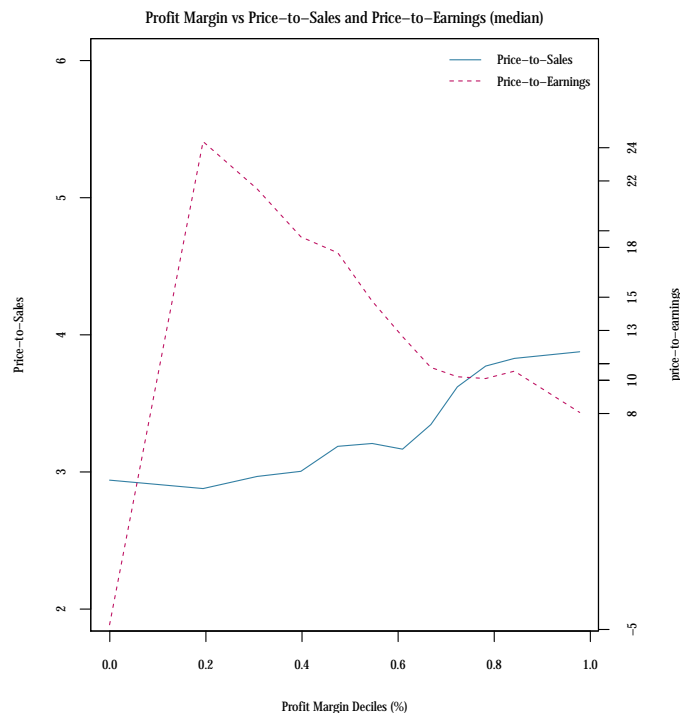
6. Market Trends

Table 11: Median Price Ratios and Leverage by Profit Margin Deciles

Median Profit Margin	Price-to-Sales	Price-to-Earnings	Leverage	n
0.03	2.56	-2.82	0.88	625
0.23	2.55	19.69	0.77	624
0.36	2.65	17.60	0.74	624
0.45	2.80	16.54	0.77	624
0.54	2.91	14.49	0.81	624
0.62	2.94	12.03	0.81	625
0.68	3.03	9.63	0.82	624
0.75	3.26	8.81	0.85	624
0.82	3.42	10.13	0.81	624
0.95	3.42	7.73	0.86	624

n is the number of observations.

Figure 18: Price-to-Sales and Price-to-Earnings Ratios by Profit Margin Deciles



The relationship between prices and profitability is described in figure 18 and table 11, which plot PSRs and PERs against the median profit margin of 10 buckets of firms sorted by profit margin, and figure 19 and table 12, which describe the data by return-on-assets (profits over total assets) buckets.

First, PSRs exhibit an increasing and positive relationship with profitability, which is explicit

and expected in equation 3.1 and confirmed by our findings in chapter 5.

Second, apart from the cases in which profitability is close to zero, PERs tend to decrease with profitability, suggesting a higher discount rate for projects that generate higher returns on assets. Profits can be less predictable in companies characterised by high financial and operational leverage, and

6. Market Trends

higher profits are likely to be more variable, impacting discount rates and the level of PERs.

The effect of profitability of the numerator of the PSR appears to be stronger than any indirect effect on the discount rate, hence an increasing PSR-by-profitability bucket. Conversely, PERs are highly impacted by higher discount rates and decrease as payout uncertainty increases with profitability.

Examining price ratios by business model in table 13 and figure 20 confirms that the relatively riskier *merchant* companies have lower PERs but also higher PSRs. This reflects their revenue-growth potential in comparison with *regulated* and *contracted* firms. We note that contracted firms, with the highest median PER, also have the highest median leverage.

6. Market Trends

Table 12: Median Price Ratios and Leverage by Return on Assets Deciles

Return on Assets	Price-to-Sales	Price-to-Earnings	Leverage	n
-0.12	2.81	-4.30	0.92	625
0.04	2.94	6.23	0.86	624
0.07	2.82	13.04	0.89	624
0.08	2.67	14.36	0.88	624
0.09	2.82	15.71	0.84	624
0.10	2.89	13.10	0.79	625
0.12	2.98	14.44	0.77	624
0.14	3.04	15.15	0.77	624
0.18	3.11	13.49	0.71	624
0.36	3.58	11.44	0.61	624

n is the number of observations.

Figure 19: Price-to-Sales and Price-to-Earnings Ratios by Return on Assets Deciles

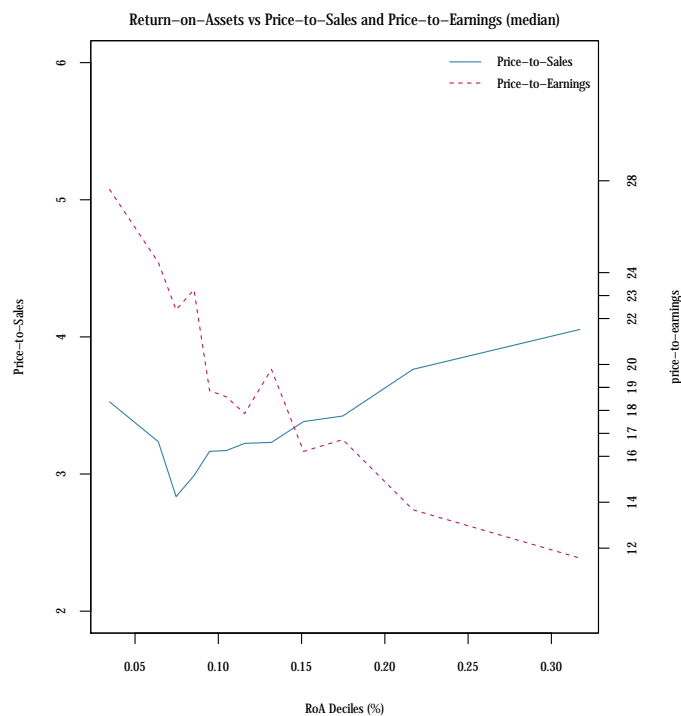


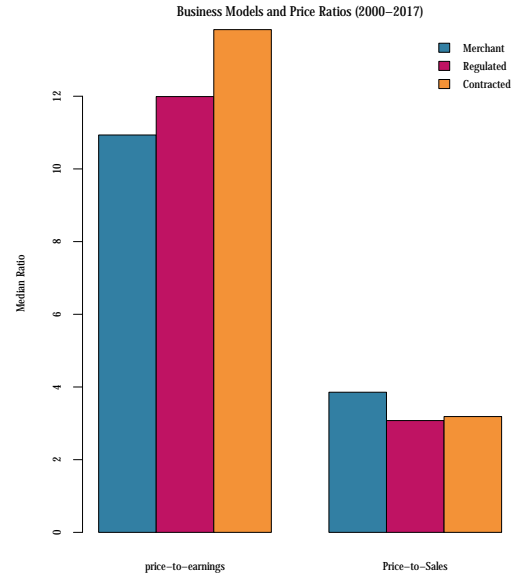
Table 13: Median Price Ratios and Leverage by Business Model

Business Model	Price-to-Sales	Price-to-Earnings	Leverage	n
Contracted	2.81	12.83	0.84	3162
Merchant	3.31	9.38	0.82	1698
Regulated	2.76	11.42	0.76	1382

n is the number of observations.

6. Market Trends

Figure 20: Price-to-Sales and Price-to-Earnings Ratios by Business Model



7. Conclusion



7. Conclusion

In this paper, we have conducted the first empirical investigation of the determinants of secondary market transaction prices for unlisted infrastructure companies. This research is relevant to the development of robust asset-pricing models for seldom traded and highly illiquid assets that nonetheless play an increasing role in the investment policy of institutional investors worldwide.

Robust measures of the value and performance of unlisted infrastructure equity investments are also relevant to the development of adequate prudential frameworks and risk-management policies.

Using a unique dataset of transactions built from the EDHEC*infra* database, we acknowledge that observable transaction prices suffer from autocorrelation and that the factors that explain their variance are likely to change sign and magnitude over time as the business cycle and investor preferences change.

In combination with the reporting bias inherent in the reporting of the data, a standard static linear model is unlikely to produce unbiased coefficient estimates.

7.1 Key Findings

We find that we can explain the variance of price-to-sales ratios using a limited number of well-known factors from the asset pricing literature, including:

1. **Size:** Larger assets are found to have lower prices, controlling for other effects.

Indeed, larger infrastructure projects are more illiquid, complex to develop, and the object of information asymmetries between buyers and sellers;

2. **Value:** During the first 10 years of their development, infrastructure projects and companies exhibit higher price-to-sales ratios despite reporting negative equity;
3. **Leverage** or credit risk: Higher leverage is found to decrease average prices;
4. **Growth:** Infrastructure companies have limited growth potential, but those that have relatively better growth options (the so-called merchant business model) have higher price-to-sales. Likewise, higher realised revenue growth tends to be associated with higher PSRs;
5. **Term:** A steeper yield curve, that is, a larger difference between long- and short-term rates lowers valuations, incorporating both a discount rate and a country risk effect;
6. **Profits:** In line with the Gordon model, higher profits tend to increase prices. We find that the effect is time-varying and most important during bad times (e.g., the years following the financial crisis).

We also control for sector-specific effects using industry-level control variables. We find that these factors explain the variance of observable transaction prices.

7.2 Hedonic Applications

Hence, with robust and unbiased coefficients, we can use the estimated factor effects to derive the average PSR of any infrastructure company at the relevant point in time.

7. Conclusion

Using the time-varying coefficient estimates described above, we consider a much larger sample of unlisted infrastructure firms that constitute a representative sample of the investable market and compute market-level PSRs and PERs.

We find that market prices for unlisted infrastructure equity have been partly evolving in line with equivalent S&P500 metrics, suggesting that investor sentiment and macro factors such as economic growth and interest rates create a degree of correlation between public equities and unlisted infrastructure.

However, the level and dynamic of unlisted infrastructure price ratios also differs from public equities in at least two important ways:

1. **PSRs are significantly higher than in public markets**, irrespective of market conditions. This reflects the ability of infrastructure companies to transform income into dividends; as highlighted in previous studies, payout ratios (dividend payouts over revenues) tend to be four to five times higher in mature unlisted infrastructure companies than in listed companies of equivalent size, leverage, and profitability (Blanc-Brude et al., 2016);
2. **PERs tend to be much more volatile than in public markets**. Indeed, payouts may be higher as share of revenues, but they are also more variable as a result of the significant financial and operational leverage that characterises infrastructure companies. Their large but mostly fixed production costs make any excess revenue

a source of pure profit, but since any decline in revenues is not easily matched with a decline in production costs, profits can decline very fast as well. Higher uncertainty of earnings can be expected to increase discount rates.

We also find that different sectors and geographies follow different trends, which is consistent with what we otherwise know of their business models.

Building on our findings about the dynamics of PSRs and PERs in unlisted infrastructure investment, several additional points stand out with regard to the valuation of unlisted infrastructure equity:

1. For the most part, **the factors driving unlisted infrastructure secondary market prices make sense**: size, leverage, value, or profitability have the signs predicted by theory, and their effects are persistent, albeit variable, across time. This is significant to defining an *ex ante* factor model of returns for the purpose of asset valuation (cf. the EDHEC*infra* Asset Valuation Methodology).
2. **Price formation and discovery is slow**: the factor effects documented above can take several years to change from one level to another, as transactions and investor preferences are processed by market mechanisms. This is partly the reflection of the status of unlisted infrastructure as a "new" asset class, so that numerous transactions were necessary over many years for "fair" prices – representing the willingness to pay of numerous buyers and

7. Conclusion

sellers at one point in time – to emerge. However, this process can be expected to stabilise as more informed buyers and sellers engage in a steady stream of transactions in the most active markets.

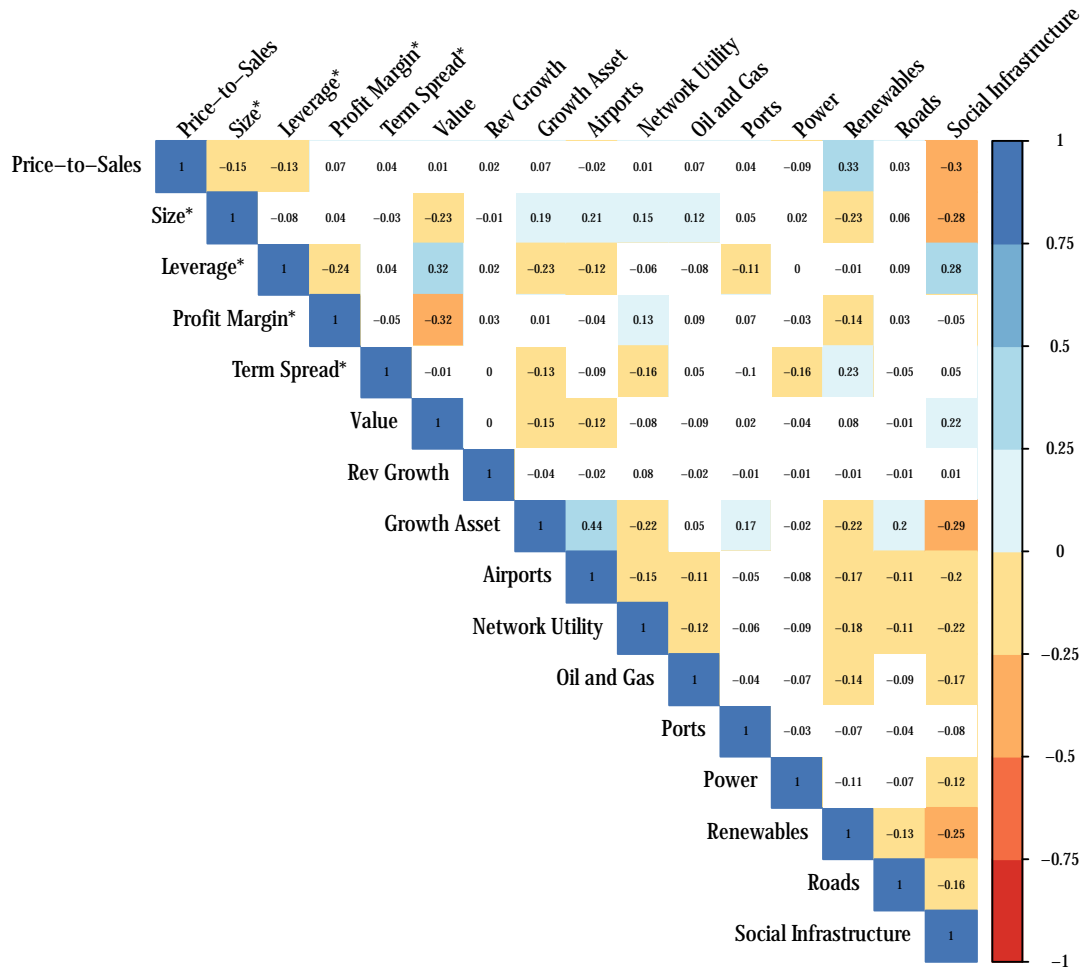
3. **Prices do not react immediately to short-term variations in financial conditions:** the swings in PERs that we documented earlier are due to the fact that prices stayed on a steadily increasing path for most of the period while earnings swung up and down, especially in the merchant sector. This can be both a function of the slow processing of price information in a high illiquid market as well as the reflection of the belief by buyers that most of the value of infrastructure companies is embodied in a long-term business model, which can be considered impervious to short-term volatility.
4. **A price consensus** may have been reached after 10 years of price increases. Infrastructure businesses are expected to deliver steady and predictable cash flows and – to the extent that this is the case – they should be expensive. Hence, a decade of price increases as more and more investors entered the market can be considered a normal process of price discovery. The significant increase in valuations that followed the 2008-2009 period has sometimes been called an infrastructure bubble. It appears however that prices have begun to stabilise, suggesting that the slow process of price discovery discussed above may have reached a certain level of stability.

A. Appendix



A. Appendix

Figure 21: Covariance Plot



Colored cells indicate statistically significant correlations at the 1% level of confidence.

Table 14: Model Residuals Hypothesis Testing

Test	Statistic	P.value
Shapiro-Wilk normality test	0.7082	0.0000
Box-Ljung test	19.824	0.7560
One-sample Kolmogorov-Smirnov test	0.045329	0.1791

A. Appendix

Figure 22: Dynamic Linear Model Residuals Normality Plots

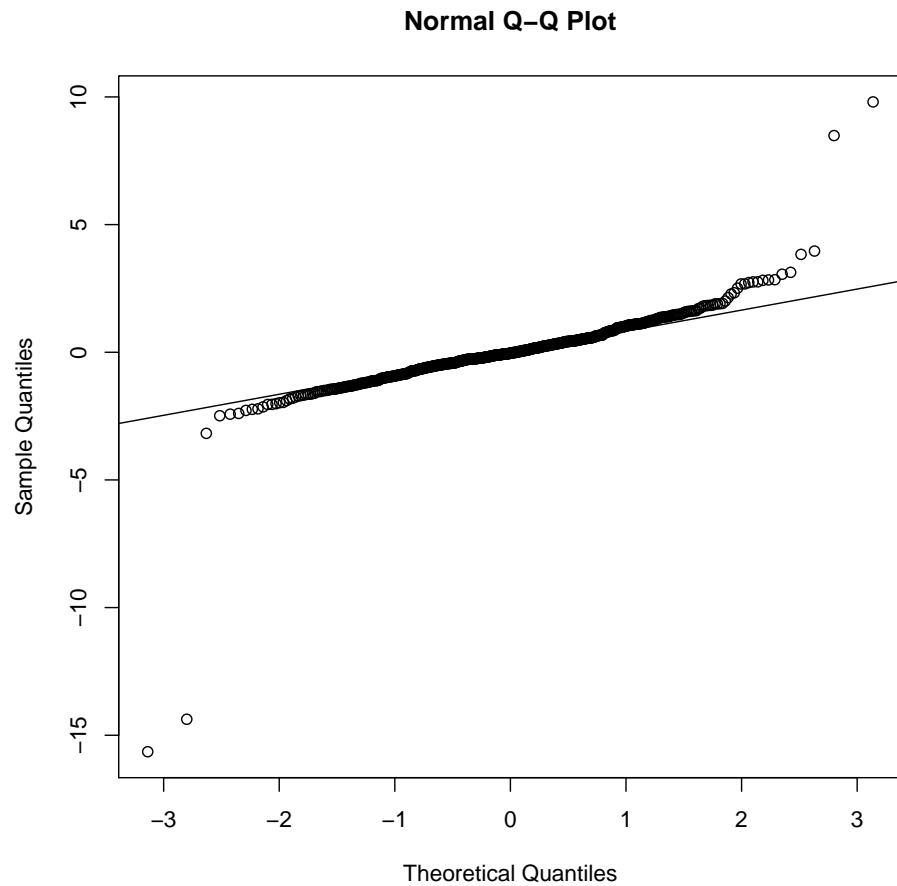
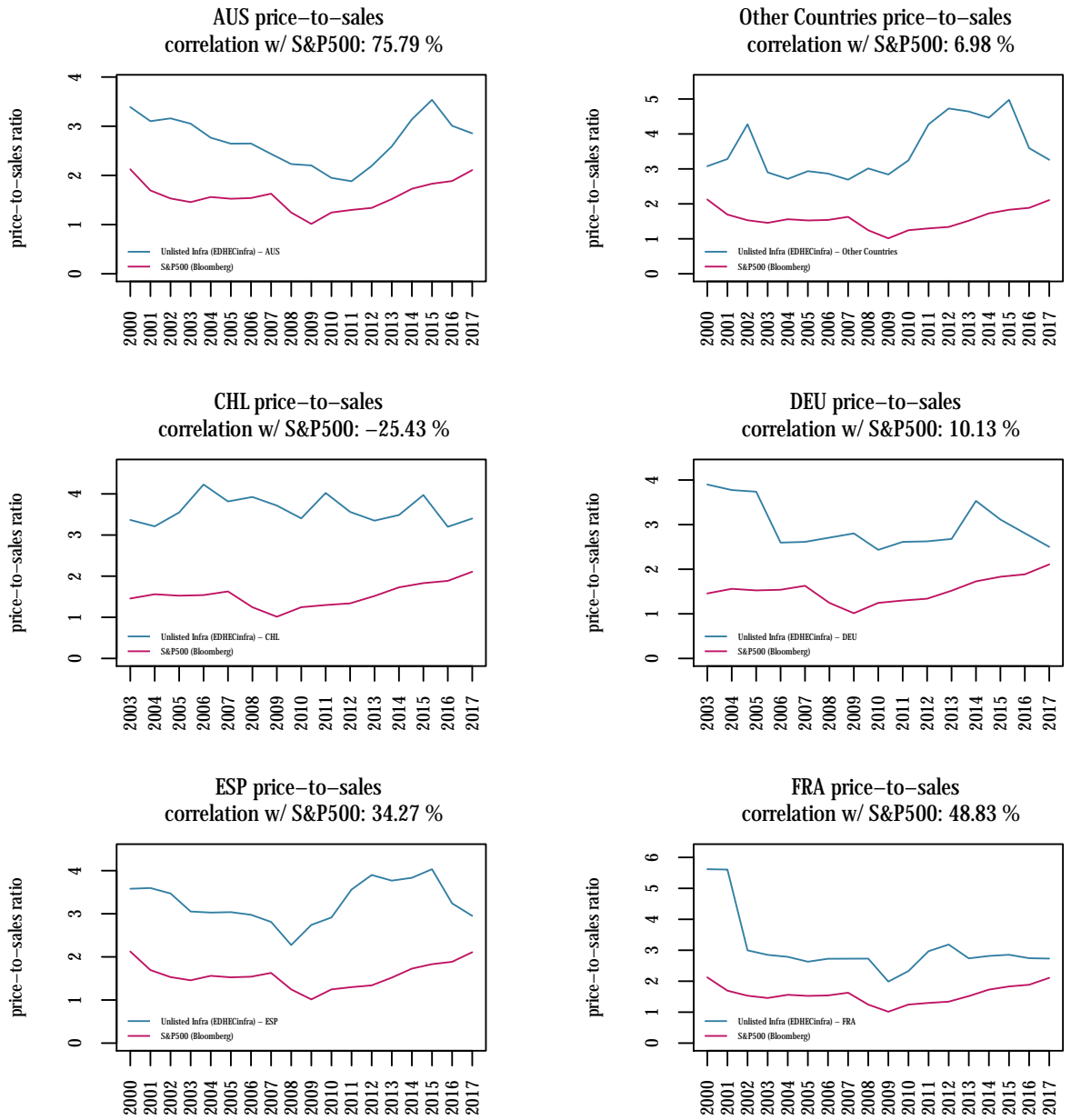


Table 15: Median Price Ratios and Leverage by Country

Country Code	Price-to-Sales	Price-to-Earnings	Leverage	n
ITA	2.45	17.75	0.72	391
SGP	2.58	9.39	0.64	130
DEU	2.65	18.37	0.71	137
GBR	2.71	12.07	0.84	2195
NZL	2.73	15.44	0.46	162
PRT	2.79	16.17	0.86	200
ESP	2.87	7.17	0.86	550
PHL	3.03	7.70	0.56	207
FRA	3.12	9.39	0.84	244
MYS	3.12	8.89	0.93	166
AUS	3.29	10.55	0.90	869
CHL	3.50	11.87	0.74	588
Others	3.63	13.92	0.84	403

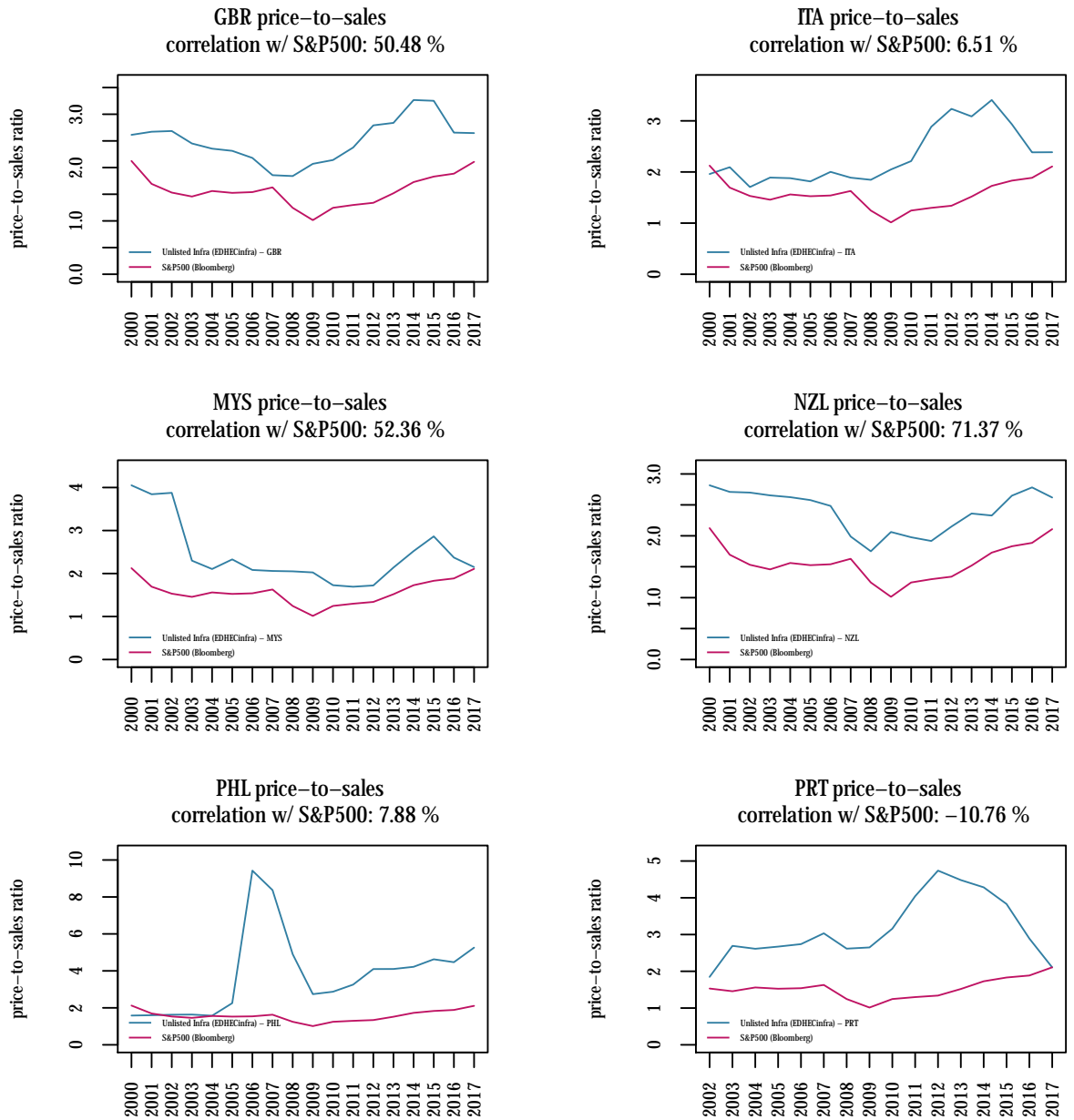
A. Appendix

Figure 23: Mean Unlisted Infrastructure and S&P500 Price-to-Sales Ratio by Country



A. Appendix

Figure 24: Mean Unlisted Infrastructure and S&P500 Price-to-Sales Ratio by Country



References



References

- Amenc, N., F. Blanc-Brude, C. Aurelie, and T. Christie (2017, October). The rise of fake infra. *EDHEC Infrastructure Institute Position Paper*.
- Amihud, Y. and H. Mendelson (1986). Asset pricing and the bid-ask spread. *Journal of Financial Economics* 17(2), 223–249.
- Ammar, S. B. and M. Eling (2015). Common risk factors of infrastructure investments. *Energy Economics* 49, 257–273.
- Beeferman, L. (2008). Pension fund investment in infrastructure: A resource paper. *Occasional Paper Series* 3, 1–78.
- Bird, R., H. Liem, and S. Thorp (2014). Infrastructure: Real assets and real returns. *European Financial Management* 20(4), 802–824.
- Bitsch, F., A. Buchner, and C. Kaserer (2010). Risk, return and cash flow characteristics of infrastructure fund investments.
- Blanc-Brude, F. (2013). Towards efficient benchmarks for infrastructure equity investments: A review of the literature on infrastructure equity investment and directions for future research.
- Blanc-Brude, F., M. Hasan, Q. Wang, and T. Whittaker (2016, March). Revenue and dividend payout in privately held infrastructure investments. *EDHEC Infrastructure Institute Publications*.
- Blanc-Brude, F., M. Hasan, and T. Whittaker (2018a). Calibrating Credit Risk Dynamics in Infrastructure Debt. *Journal of Fixed Income* 27, 54–71.
- Blanc-Brude, F., M. Hasan, and T. Whittaker (2018b). Calibrating credit risk dynamics in private infrastructure debt. *Journal of Fixed Income* 27(4), 54–71.
- Brennan, M. J. and A. Subrahmanyam (1996). Market microstructure and asset pricing: On the compensation for illiquidity in stock returns. *Journal of Financial Economics* 41(3), 441–464.
- Bucks, P. (2003). Financial leverage and the regulator. *Utilities Journal* 6(10), 38–39.
- Carhart, M. M. (1997). On persistence in mutual fund performance. *Journal of Finance* 52(1), 57–82.
- Esty, B. C. and W. L. Megginson (2003). Creditor Rights, Enforcement, and Debt Ownership Structure: Evidence from the Global Syndicated Loan Market. *Journal of Financial and Quantitative Analysis* 38(1), 37–59.

References

- Fama, E. F. and K. R. French (1992). The cross-section of expected stock returns. *Journal of Finance* 47(2), 427–465.
- Fama, E. F. and K. R. French (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics* 33(1), 3–56.
- Finkenzeller, K., T. Dechant, and W. Schäfers (2010). Infrastructure: a new dimension of real estate? an asset allocation analysis. *Journal of Property Investment & Finance* 28(4), 263–274.
- Hartigan, L. R., R. Prasad, and A. J. De Francesco (2011). Constructing an investment return series for the uk unlisted infrastructure market: Estimation and application. *Journal of Property Research* 28(1), 35–58.
- Humphreys, T., G. Maclean, and J. Rogers (2016). Equity infrastructure valuations: Leads, lags and controversies. *Industry report, AMP Capital, Sydney*.
- Inderst, G. (2010). Infrastructure as an asset class. *EIB papers* 15(1), 70–105.
- Martellini, L. and V. Milhau (2015). Factor investing: A welfare improving new investment paradigm or yet another marketing fad. *EDHEC-Risk Institute Publications*.
- Newell, G., H. W. Peng, and A. De Francesco (2011). The performance of unlisted infrastructure in investment portfolios. *Journal of Property Research* 28(1), 59–74.
- Petkova, R. and L. Zhang (2005). Is value riskier than growth? *Journal of Financial Economics* 78(1), 187–202.
- Petris, G., S. Petrone, and P. Campagnoli (2009). *Dynamic Linear Models with R*. Springer, London.
- Priemus, H., B. Flyvbjerg, and B. van Wee (2008). *Decision-Making on Mega-Projects: Cost-Benefit Analysis, Planning and Innovation*. Edward Elgar Publishing.
- Standard and Poor's (2018, October). Index mathematics methodology.
- Vassalou, M. and Y. Xing (2004a). Default risk in equity returns. *Journal of Finance* 59(2), 831–868.
- Vassalou, M. and Y. Xing (2004b). Default risk in equity returns. *Journal of Finance* 59(2), 831–868.
- Wen Peng, H. and G. Newell (2007). The significance of infrastructure in Australian investment portfolios. *Pacific Rim Property Research Journal* 13(4), 423–450.

About The Long-Term Infrastructure Investors Association



About The Long-Term Infrastructure Investors Association

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

Our principal activities include:

- public advocacy and engagement with policy-makers;
- investment in research and innovation for the benefit of infrastructure investors;
- education and training on long-term investing in infrastructure.

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



About EDHEC Infrastructure Institute-Singapore



About EDHEC Infrastructure Institute–Singapore

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

Origins

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

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

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

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

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

A Profound Knowledge Gap

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

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

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

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

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

Mission Statement

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

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

About EDHEC Infrastructure Institute-Singapore

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

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

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

What We Do

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

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

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

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

Partners of EDHEC*infra*

Monetary Authority of Singapore

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

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

Sponsored Research Chairs

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

About EDHEC Infrastructure Institute–Singapore

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

Partner Organisations

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

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

EDHEC*infra* is also :

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

EDHEC Infrastructure Institute Publications



EDHEC Infrastructure Institute

Publications

EDHEC Publications

- Blanc-Brude, F., A. Chreng, M. Hasan, Q. Wang, and T. Whittaker. "Private Infrastructure Equity Indices: Benchmarking European Private Infrastructure Equity 2000-2016" (June 2017).
- Blanc-Brude, F., A. Chreng, M. Hasan, Q. Wang, and T. Whittaker. "Private Infrastructure Debt Indices: Benchmarking European Private Infrastructure Debt 2000-2016" (June 2017).
- Blanc-Brude, F., G. Chen, and T. Whittaker. "Towards Better Infrastructure Investment Products: A Survey of Investors' Perceptions and Expectations from Investing in Infrastructure" (July 2016).
- Blanc-Brude, F., T. Whittaker, and S. Wilde. "Searching for a Listed Infrastructure Asset Class: Mean-Variance Spanning Tests of 22 Listed Infrastructure Proxies" (June 2016).
- Blanc-Brude, F., T. Whittaker, and M. Hasan. "Cash Flow Dynamics of Private Infrastructure Debt" (March 2016).
- Blanc-Brude, F., T. Whittaker, and M. Hasan. "Revenues and Dividend Payouts in Privately-Held Infrastructure Investments" (March 2016).
- Blanc-Brude, F., and M. Hasan. "The Valuation of Privately-Held Infrastructure Equity Investments" (January 2015).

Peer-Reviewed Publications

- Hasan, M., and F. Blanc-Brude. "You Can Work It Out! Valuation and Recovery of Private Debt with a Renegotiable Default Threshold." *Journal of Fixed Income*, 26(4), 2017, pp. 113-127.
- Blanc-Brude, F., S. Wilde, and T. Witthaker. "Looking for an Infrastructure Asset Class: Definition and Mean-Variance Spanning of Listed Infrastructure Equity Proxies." *Financial Market & Portfolio Management*, 31, 2017, pp. 137-179.
- Blanc-Brude, F., and M. Hasan. "A Structural Model of Credit Risk for Illiquid Debt." *Journal of Fixed Income*, 26(1), 2016, pp. 6-19
- Blanc-Brude, F., M. Hasan, and T. Witthaker. "Benchmarking Infrastructure Project Finance—Objectives, Roadmap and Recent Progress." *Journal of Alternative Investments*, 19(2), 2016, pp. 7-18
- Bianchi, R., M. Drew, E. Roca, and T. Whittaker. "Risk Factors in Australian Bond Returns," *Accounting & Finance*, 2015.

EDHEC Infrastructure Institute Publications

- Blanc-Brude, F. "Long-Term Investment in Infrastructure and the Demand for Benchmarks." *JASSA: The Finsia Journal of Applied Finance*, 3, pp. 57–65, 2014.

For more information, please contact:
Karen Sequeira on +65 6438 0030
or e-mail: karen.sequeira@edhec.edu

EDHEC Infrastructure Institute
EDHEC Asia-Pacific
One George Street - #15-02
Singapore 049145
Tel.: +65 6438 0030

edhec.infrastructure.institute