Is Infrastructure Shockproof?

The Resilience of Infrastructure Equity Investments During Market Downturns, 2000-2022

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Executive Summary

In this paper, we compare the behaviour of unlisted infrastructure equity investments with that of traditional assets, with a focus on the effects of shocks such as recessions, financial market crises and policy shocks. We compare the return correlations and drawdown characteristics of geographically comparable indices of unlisted infrastructure equity, listed equity, treasuries and corporate bonds. We then examine their return drawdown and co-variance, as well as higher co-moments of returns (co-skewness and co-kurtosis), to determine the presence or absence of joint extreme risks.

To make this analysis possible, we use 22 years of monthly returns from infraMetrics® to proxy unlisted infrastructure returns. We build geographically comparable public equity and bond indices to use as as our comparators. We revealed the following stylised facts:

1. **Unlisted infrastructure is not immune to market shocks**: Infrastructure asset prices exhibit a similar behaviour in times of stress as other asset classes: economic, financial, and policy shocks lead to lower asset values. They also lead to higher cash returns since infrastructure companies taken on aggregate tend to pay very stable dividends. In other words, we do not find zero or negative correlations between infrastructure and capital markets; instead we find positive, significant and time-varying return correlations between unlisted infrastructure equity and both stocks and bonds.

2. **There is good evidence of downside protection**: The level of drawdown and extreme losses exhibited by unlisted infrastructure equity during periods of market stress is lower than in listed equities, greater than government bonds and often close to cthat of orporate bonds.

3. **Risk premia correlations increase in bad times**: Unlisted infrastructure returns become more positively correlated with listed equities in times of crisis. The two also share some tail risk; this was especially the case during the subprime crisis and the Covid pandemic, when extreme co-movements of returns occurred more frequently. This coincidence of losses in bad times is due to simultaneous increases in the equity risk premia of each asset class.

4. **Interest rate risk matters**: Infrastructure equity investments share characteristics with bonds, especially via their exposure to interest rate risk. Return correlations with bonds are always positive and robust, while shocks to the level of interest rate impact infrastructure quite as much as bonds of comparable duration and convexity. Infrastructure equity also shares some tail risk with corporates bonds but not of the same order of magnitude as with listed equity, i.e., corporate credit spreads do not covary a lot with the infrastructure equity risk premia. Infrastructure equity does not exhibit common tail risk with government bonds.

5. **Different types of infrastructure weather shocks differently**: Comparing a highly contracted and project-based segment of the unlisted infrastructure sector (social infrastructure) with more regulated (utilities) or merchant sectors (transports) reveals that discount rate shocks can have a greater impact on contracted infrastructure. The more stable (and usually long) cash-flow profile of contracted assets makes them more vulnerable to rate shocks because they cannot

grow future cash flows commensurably. BY contrast, riskier business models like regulated utilities or toll roads can partly offset higher rates with higher future cash flows, because they benefit from either an inflation pass-through or pricing power.

6. **Not all shocks have the same impact**: Different types of shocks impact infrastructure investments differently: recessions coincide with lower returns through the cash flow channel but also because of a general increase in risk premia. Financial crises also lead to higher risk premia and typically a higher level of stress. However, a public debt crisis like the Eurozone crisis does not have this effect; this is consistent with the absence of joint tail risk as shown by the very low higher return co-moments between infrastructure and government bonds.

7. **Inflation risk is really interest rate risk**: Inflation risk is difficult to observe directly given the absence of inflation shocks in the past 20 years of data, with the exception of the first months of 2022. However, to the extent that higher inflation leads to immediate and positive shifts in the yield curve, it is strongly related to interest rate risk, which is well-documented over the past 20 years, especially the sensitivity or return in a very low rate environment. As interest rates increase, the long duration of infrastructure can imply large losses. However, different levels of convexity – sensitivity to large changes in rates – are found in infrastructure business models and imply different levels of exposure. More infrastructure-focused businesses can partly offset higher discount rates thanks to higher cash flows, either from revenue indexation or growth.

8. **Infrastructure is good for the portfolio**: Infrastructure remains a potent diversifier of the portfolio even in times of stress. While correlations with capital markets do increase in bad times, they remain limited and the level of drawdown is much lower in infrastructure, especially on a total return basis. Still, the more extreme the risk and the deeper the impact on the economy, the more infrastructure investments tend to correlate with capital markets. This is consistent with the essential role played by infrastructure in an economy.

It should be noted that these results assume a well-diversified exposure to unlisted infrastructure assets and provide a comparison of risk and performance for many assets. The main infrastructure index used in this study is the infra300® which includes 300 constituents. In practice, many investors may find themselves less diversified because unlisted infrastructure investments are large and illiquid, and it take times to build a significant portfolio. As a result, many investors in unlisted infrastructure equity may be more at risk than these results suggest.

These findings have risk management and prudential implications. They show that, in times of market stress, while infrastructure does experience drawdowns and is exposed to a market risk premia and to a significant rate risk, it can nonetheless protect the portfolio on the downside – just as long as investor are exposed to a well-diversified basket of infrastructure assets in which most asset-specific risk has been diversified. This informs the evolution of the treatment of infrastructure assets under the EU Solvency framework or other prudential regulations. The resilience of infrastructure investments also explains, in part, why they have become increasingly attractive to investors– along with their ability to generate high income returns over the past two decades. These results also give some insights into what climate risks might look like for infrastructure investors; transition risk are mostly policy driven and would impact many assets at the same time, effectively resetting future cash flows and the level of discount rates reflecting the risk of future cash flows.

Contents

Foreword

As one of its key its missions of LTIIA Since its inception has been to support research by academic centres such as EDHECinfra with a view to promote unlisted infrastructure becoming a fully-fledged asset class. Our continuous aim to support data collection and the development of analytical tools and performance benchmarks for the investment community.

Accordingly, in 2021, LTIIA supported a new study by EDHECinfra on the Infrastructure assets "drivers of volatility", which showed that there is a higher return volatility in Infrastructure than typically perceived, in part driven by interest rates and risk premia (the "duration" effect). This year, building up on that study, LTIIA wanted to check investigate the oft-discussed 'resilience' of infrastructure equity to external shocks, in what appears to be very volatile times economically and politically.

EDHECinfra could do this work as scientifically as possible, thanks to its large data-set, covering hundred of assets over a long period of time.

The study offers a granular image of how unlisted infrastructure behaves in a number of situations, and confirms rather than upends, previous insights about Infrastructure's overall protective and diversification effect (To sum it up, infrastructure is good for the portfolio!), we see it as important and timely in two ways:

1. Firstly, it takes place at a time of strategic re-allocation of assets in many Institutional investors' portfolios : with the recent inflationary bout, a big concern for institutional. investors, the trend is towards increasing the weight of real assets, seen by 4 out of 5 investors as providing an effective inflation hedge. Within the real assets category, infrastructure seems prone to benefit from an asset allocation point of view. This seems to be supported by the record breaking levels of fund raising for Infra Funds ($70b in Q1, over 30b in Q2). Such a study may reinforce and support this trend.
2. We also see this study as relevant from a prudential standpoint, which is useful in 2022/23 as updating work is scheduled by regulators in unlisted infrastructure, under the EU Solvency framework or other prudential regulations.

It is our shared responsibility now, and LTIIA will do its bit, to convey and disseminate those results to the main interested stakeholders, starting with regulators, so that policy frameworks better reflect these findings and ideally encourage more long-term investment in the infrastructure assets needed to face some of the most important challenges we face collectively.

Wishing you a good read!

Vincent Levita

President, LTIIA

CEO & Founder, Infravia

1. Introduction

In this paper, we compare the behaviour of unlisted infrastructure equity investments with that of traditional assets, with a focus on the effects of shocks such as recessions, financial market crises and policy shocks. We compare the return correlations and drawdown characteristics of geographically comparable indices of unlisted infrastructure equity, listed equity, treasuries and corporate bonds. We then examine their return drawdown and co-variance, as well as higher co-moments of returns (co-skewness and co-kurtosis), to determine the presence or absence of joint extreme risks.

There are several reasons why infrastructure equity returns could become more correlated with those of capital markets during times of economic or financial distress. Three factors play a role in the co-variance of infrastructure valuations: future cash flows and the two components of their market discount rate, namely the (unlisted) infrastructure equity market risk premium and the bond yield curve at the relevant horizon. The extent to which infrastructure asset prices are impacted by market downturns is a combination of their sensitivity to changes in these three quantities. In particular, interest rates and risk premium shocks can be expected to drive any extreme co-moments of returns between unlisted infrastructure and public asset classes.

In terms of future cash flows, because infrastructure companies provide essential services, demand can be expected to be resilient in bad times. Moreover, infrastructure companies derive their value from a long-term business model and payback period. Hence, their value should be less sensitive to short-term fluctuations in demand for services and revenues. That said, even if the value of long-term and essential assets is not materially impacted by small or brief downturns in economic activity, infrastructure is nonetheless the backbone of the economy and derives its value from its continued future activity. Hence, large economic or policy shocks can have a significant impact on the future cash flows of some infrastructure businesses, precisely when other asset classes also exhibit large losses, adding an element of systematic risk.

Next, the present value of infrastructure equity investments is a function of a risk premium that represents the market price of the risk of future cash flows. This premium is in part the reflection of the supply and demand for unlisted infrastructure investments which, in itself, is dependent on investors' arbitrage choices between different asset classes (including between alternative asset classes), the evolution of their risk preferences, and the market price of the various risk factors that drive this premium. In times of market stress, the listed equity market premium and the unlisted infrastructure equity market premium can be expected to become more correlated, as investors' preferences for low risk and liquid assets increases concurrently.

Likewise, the level of interest rates is a conduit through which unlisted infrastructure and capital markets could become more correlated in times of crisis. The long-term nature of infrastructure investments implies a significant duration i.e., a higher sensitivity of asset values to changes in discount rates and in particular to shifts in the yield curve when interest rates are already very low. Such duration alone can be expected to create correlations between infrastructure investments and bonds.

Table 1 from infraMetrics® shows the individual impact of actual changes in each factor on unlisted infrastructure asset values (leaving the

other two factors unchanged): movements in rates and risk premia play a role in the variance of infrastructure asset prices that is at least as significant as that of aggregate dividend growth. In times of crisis, even if infrastructure cash flows are resilient, investors should anticipate some downside risk due to a likely increase in the risk premium and, depending on the nature of the shock, a potential increase in the level of interest rates.

Finally, certain types of infrastructure are also more exposed to downturns than others: infrastructure companies with a so-called 'merchant' business model such as toll roads or merchant power plants see their revenues fluctuate with the business cycle. Not only is their equity risk premium higher than that of infrastructure companies with a more predictable business model such as 'contracted' infrastructure projects, but it is also more likely to co-vary with the equity risk in capital markets. However, merchant and regulated assets are also more likely to exhibit future cash flow growth, including through tariff indexation and monopoly pricing power, partly offsetting the impact of higher interest rates on their valuation and returns. Contracted assets however, may only hedge movements in discount rates if they have contractually defined inflation pass-through. Thus, for a given duration, contracted infrastructure investments may be more exposed to interest rate risks, including inflation-driven rate increases, while merchant and regulated infrastructure may better protect real returns through cash flow growth.

Methodologically, we choose to avoid the so-called event-based approaches where individual events or shocks directly affect infrastructure returns. Instead, we focus on material changes in capital market benchmarks as potential shocks and analyse the co-moments of the infrastructure asset class with these financial benchmarks. Thus, we address both the question of whether infrastructure returns are resilient during crisis but also the downside protection afforded by infrastructure to investors that include this asset class in their portfolio. A key driver for this analysis is the ability to use the full distribution of monthly returns for unlisted infrastructure equity available through infraMetrics® that allows characterisation of the tail risks in infrastructure compared with those of stocks and bonds in a statistically robust manner.

We consider three types of shocks or market downturns:

- Recession: Economic shocks as indicated by period of economic contraction
- Drawdown: Financial shocks characterised by periods of asset price decreases
- Policy shocks: Sudden changes in policies that have economic and financial consequences, e.g. Covid-19 lockdowns

Because infrastructure equity investment investments have a significantly higher cash yield than either stocks or bonds, we conduct this analysis using both price returns (capital returns) on the one hand and total returns on the other. Indeed, cash returns make up a significantly larger share of total returns in infrastructure investments than they do in public equities or even bonds (see section 2). Price returns provide a like-for-like comparison of the joint impact of shocks on the value of infrastructure assets and capital markets.

To investigate these questions, we use 22 years of monthly returns from infraMetrics® to proxy unlisted infrastructure returns. We build geographically comparable public equity and bond indices as our comparators. It should be noted that these results assume a well-diversified exposure to unlisted infrastructure assets and provide a comparison of risk and performance for many assets. The main infrastructure index used in this study is the infra300® which includes 300 constituents. In practice, many investors may find themselves less diversified because unlisted infrastructure investments are large and illiquid,

Table 1: Individual impact on net asset values of changes in expected cash flows, risk premia and interest rates - global infrastructure equity

Change in NAV	Due to a % change in dividend forecast	Due to a % change in interest rates	Due to a % change in equity risk premium
Last one-ear avg	2.1%	-6.3%	-1.5%
Last three-year avg	2.5%	-2.6%	-6.2%
Last five-year avg	3.3%	1.6%	-8.3%

This analysis shows the average change in NAV due to a change in dividend forecast, interest rates and the equity risk premium. It does not include any impact from paid-out dividends. These results should be read thus: "Over the past five years, a 1% change in the level of interest rates/future dividends/risk premia, each, caused an average cumulative change in the NAV of X%." Source: infraMetrics® 2022

and it take times to build a significant portfolio. As a result, many investors in unlisted infrastructure equity may be more at risk than these results suggest.

The rest of this paper is structured thus: section 2 defines the types of shocks used to compare unlisted infrastructure with capital markets and describes the equity and bond market benchmarks used to conduct the analysis. Next, section 3 compares the risk-adjusted performance of infrastructure with capital markets in times of stress while section 4 proposes a comparative analysis of the drawdown and recovery of each asset class over time. Section 5 further discusses the evolution of return correlations between unlisted infrastructure and capital markets. Next, section 6 looks at the transmission mechanisms between asset classes, in particular the role of interest rates and the equity risk premium. Finally, section 7 shows a more granular set of results for three key segments of the infrastructure universe.

2. Shock Definitions and Market Benchmarks

In this section we describe the three types of shocks that will be used in this study as well as the design of capital market benchmarks that are consistent with the geographic exposures of the unlisted infrastructure equity market index.

2.1 Shock definitions

From the standpoint of the infrastructure asset class, we consider shocks or downturns as exogenously generated: they are not the result of infrastructure investments decisions. Recessions, capital market sell-offs and policy shocks occur for reasons that are independent of the activity of investors in the unlisted infrastructure space. Hence, while some of this activity may have been supported by general market conditions, infrastructure investments cannot be considered to have significantly contributed or triggered any of the shocks in question. We therefore assume no endogeneity (feedback loop) and simply observe the behaviour of infrastructure investments in their economic and financial context. We consider the following three types of shocks:

- Six periods of economic recessions as defined and reported by the OECD for its member countries (dates indicating the start and end of GDP contraction periods):
  1. July 2000 to April 2003
  2. January 2007 to May 2009
  3. December 2011 to January 2013
  4. July 2015 to July 2016
  5. April 2018 to May 2020

- Financial shocks are defined as periods of market drawdown (peak-to-through) during which asset prices expected a continuous decline. For each asset class we examine, we consider the 10 largest drawdowns since 1999, including:
  1. The dot-com and power crash (2001)
  2. The 2002 market sell-off
  3. The subprime crash (2008)
  4. The Eurozone debt crisis (2011)
  5. The 2015 market sell-off
  6. The 2018 crash

- Policy shocks are events that force the policy maker to make unexpected policy changes that durably damages economic activity and asset values through a combination of impacts on expected cash flows, the risk premium and the yield curve. We consider the following events:
  1. 9-11 (2001)
  2. Brexit (2016)
  3. Covid-19 (2020)
  4. The Ukraine war (2022)

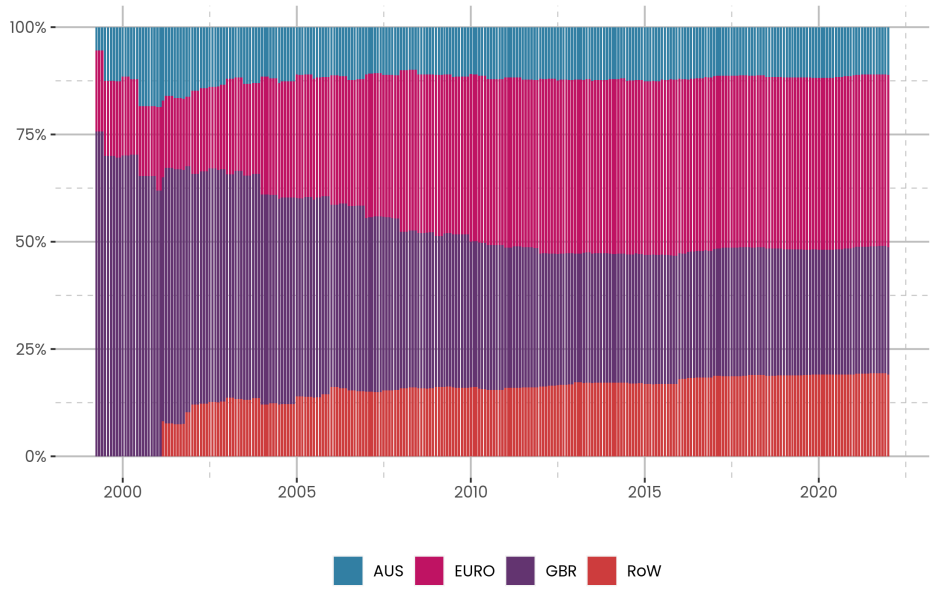
Next, we describe the reference capital market benchmarks we use to compare the impact of shocks on asset prices with that of unlisted infrastructure equity investments.

2.2 Infrastructure and capital market benchmarks

We use the infra300® index as the proxy of global unlisted infrastructure equity investments. This index tracks the performance of 300 unlisted infrastructure companies and is designed to be representative of an underlying universe of 25 countries representing more than 8,000 identified individual infrastructure equity investments, in terms of TICCS® segments [1] across business risks, industrial activity, and corporate structure

1 - See The Infrastructure Company Classification Standard, 2022 Ed. https://docs.edhecinfra.com/pages/viewpage.action?pageId=4259902

Figure 1: Broad regional split of the infra300® Index universe.



Source: infraMetrics®

Table 2: 10-yr Average Duration of Infrastructure Equity and Reference Bond Benchmarks

Type	RoW	AUS	EURO	GBR
Government Bond Benchmark	7.670	11.1806	9.4481	9.6619
Corporate Bond Benchmark	6.463	7.3123	10.0369	9.3672
Infrastructure Equity (infraMetrics)	8.425	10.6470	10.2039	9.1628

dimensions. As of Q1 2022 the infra300® index had a market capitalisation of USD240bn.[2]

To compare unlisted infrastructure equity with a representative proxy of capital markets, we build three reference benchmarks reflecting the geographical composition of the infra300® index universe over time. Indeed, the unlisted infrastructure market is biased towards certain regions and countries, those where governments have privatised infrastructure earlier and more broadly. The composition of this available market has evolved considerably since 2000 as more jurisdictions introduced infrastructure privatisation programmes and rolled out various public-private partnership procurement models. Figure 1 shows the broad regional composition of the infra300® universe since 2000, split between the Eurozone, UK, Australia, and the rest of the world (RoW).

2 - For this exercise, we use an equally-weighted, local currency return version of the index, so that results are not impacted by larger weights or changes in foreign exchange rates - see Appendix for more details.

Using the same geographic weights, we compute three local currency reference portfolios for listed equities, government bonds and corporate bonds using the following four indices for each region:

- Listed Equities:
  - Eurozone: FTSE World Eurozone (EUR)
  - UK: FTSE All Shares (GBP)
  - Australia: MSCI Australia (AUD)
  - Rest of the World: MSCI World (USD)
- Government Bonds:
  - Eurozone: European Monetary Union Total 7-10 Years Datastream Government Index (EUR)
  - UK: iBoxx United Kingdom Sterling Sovereigns and Subordinated-Sovereigns 10-15 (GBP)
  - Australia: Australia 7-10 Years Datastream Government Index (AUD)
  - Rest of the World: United States Tracker 7-10 Years Datastream Government Index (USD)

- Corporate Bonds:
  - Eurozone: iBoxx Euro Corporates 10-15 Years (EUR)
  - UK: iBoxx United Kingdom Sterling Corporates 10-15 Years (GBP)
  - Australia: The S&P/ASX Corporate Bond Index (AUD)
  - Rest of the World: The Bloomberg Global Aggregate Index (USD)

For example, reference benchmark returns $r_{equities,t}$ for listed equities are computed thus:

$$r_{equities,t} = \omega_{europe,t} \times \text{FTSE Eurozone} + \omega_{UK,t} \times \text{FTSE All Shares} + \omega Australia, t \times MSCIAustralia + \omega_{RoW,t} \times \text{MSCI World}$$

where $\omega_{i,t}$ is the weight of region i at time t, as shown on figure 1.

To control for the impact of changes in interest rates, we select government and corporate bond indices with comparable duration to that of the infra300® universe. Table 2 shows the absolute percentage change in value for a one percent change in discount rate or modified duration. We see that the duration of the reference indices used to build the government and corporate bond benchmarks are congruent with that of unlisted infrastructure equity investments in the relevant geographies. Hence, when we compare the impact of shocks on bonds relative to infrastructure, the effect of small shifts in the yield curve on valuations can be considered equivalent.

Next, we examine the risk-adjusted performance of the infra300® and capital market benchmarks during shocks.

3. Risk-Adjusted Performance

3.1 Risk-adjusted performance profile

We examine 22 years of monthly returns for our capital market benchmarks and the infra300® index.[1] Tables 4 and 3 show the performance, volatility, and risk-adjusted returns for each asset class.

Unlisted infrastructure delivers higher return volatility than that of bonds but lower than that of listed equities, which is consistent with its economic characteristics. Note that the risk (annualised standard deviation of returns) of the infra300® index is lower when calculated on a total return basis than when using price returns. This is not the case for the capital market benchmarks and is a testament to the importance of cash yields in infrastructure returns, including as a source of return stability.

On a risk-adjusted basis, unlisted infrastructure equity has a more attractive in-sample Sharpe ratio than other asset classes. We have shown in a previous paper (Blanc-Brude et al., 2021) that the significant increase in infrastructure asset valuations that occurred during the 2010-2017 period, as demand for this type assets increased rapidly, led to substantial but finite capital gains that explain the high historic risk-adjusted performance of the unlisted infrastructure asset class and its very high realised Sharpe ratio.

On a forward-looking basis, the 2022 Sharpe ratio of infrastructure equity is lower. Using infraMetrics data, average expected returns in 2022 for global unlisted infrastructure equity are around 8%. Using historical volatility as a proxy of forward-looking risk, the forward-looking Sharpe ratio of unlisted infrastructure is close to 0.6, which remains attractive when compared with capital markets, especially equities.

Next, figure 2 shows the distributions of price (2a) and total returns (2b) for government bonds, equities, and unlisted infrastructure equity (corporate bonds are omitted for readability). Tables 4 and 3 also show the skewness and excess kurtosis of the distribution of returns, which are indicators of asymmetric and extreme risks.

Unlisted infrastructure exhibits less extreme risk (absence of fat tails) than equities or corporate bonds as suggested by their respective excess kurtosis. Likewise, infrastructure exhibits lower negatives skewness than equities or corporate bonds. Very negative returns are clearly possible with infrastructure equity but there is a 10-20bp difference between the skewness of equities and corporate bonds returns and that of the infra300®.

On aggregate, the risk-adjusted profile of unlisted infrastructure can be described as 'between equities and bonds' with common negative skewness with equities (we return to large drawdown analysis in section 4) but an absence of fat tails (lower kurtosis) that is more akin to Treasuries.

3.2 Performance during shocks

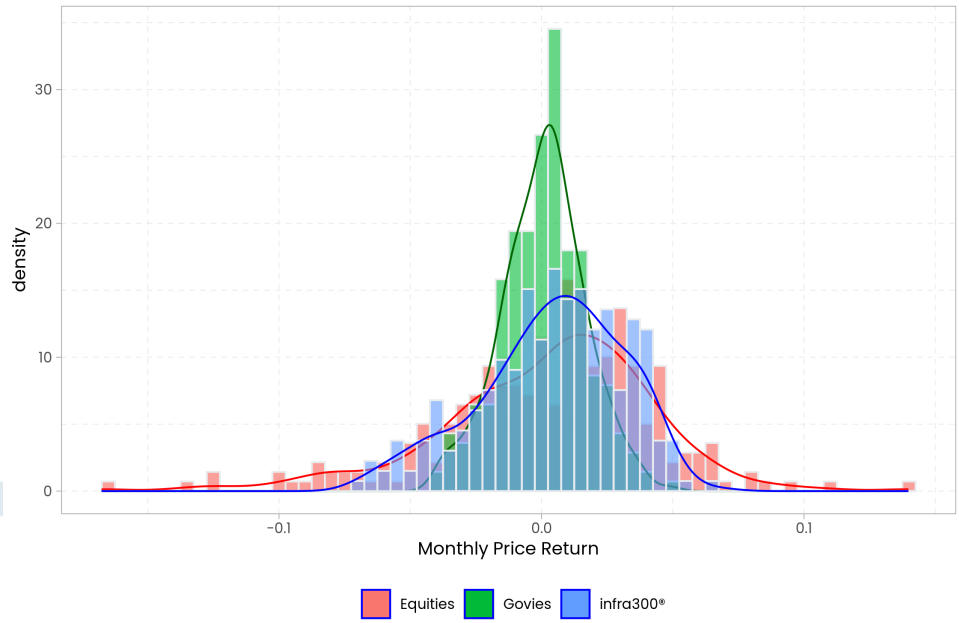
In effect, whether infrastructure investments behave more like bonds or equities depends on the time period and type of market stress involved.

Figures 3 and 4 show the price, total returns and cash returns of the infra300® index and its three comparators over time. The figures also show periods of economic recession in grey and

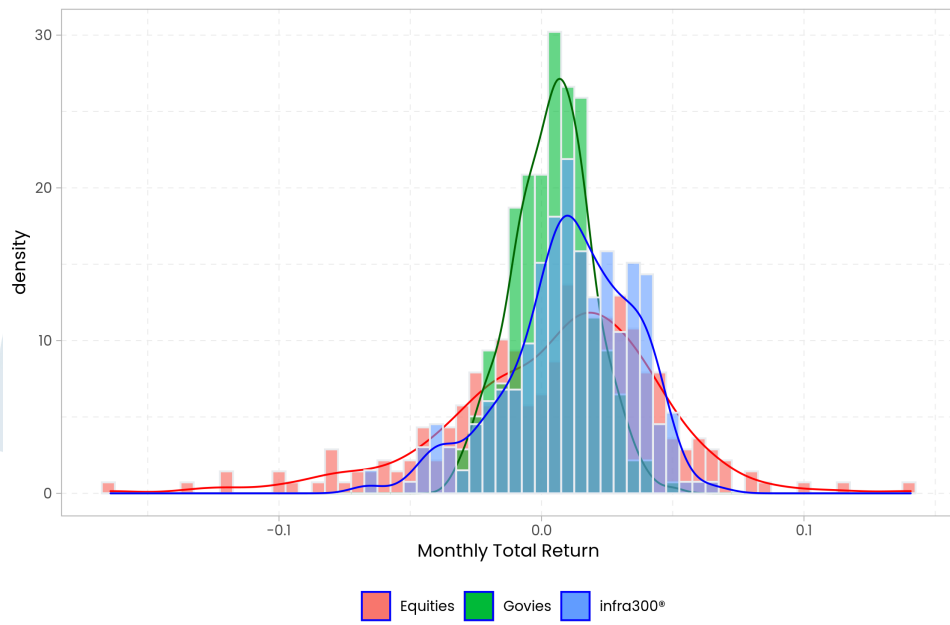
1 - Note that such an analysis, however simple, was not possible until recently because monthly performance data was not available for research. infraMetrics started publishing monthly data in the Fall of 2021.

Figure 2: Monthly return distributions, reference market benchmarks and infra300®

(a) Price returns



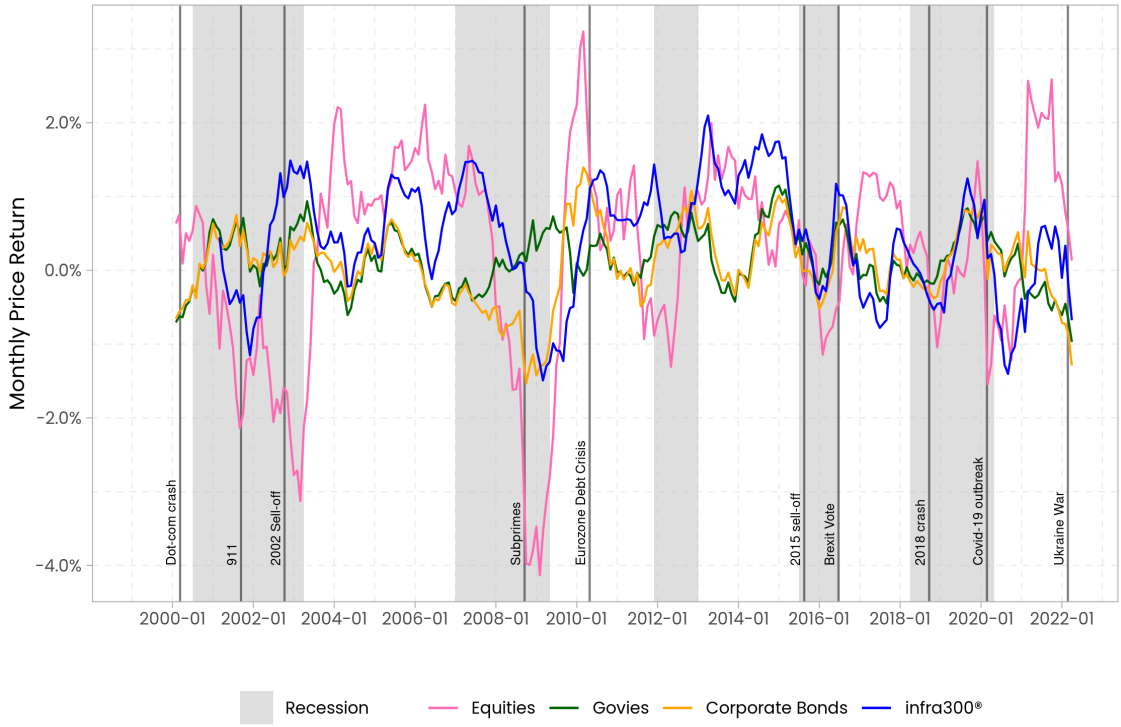
(b) Total returns



Source: Datastream, infraMetrics®

Figure 3: 12-Month average returns, reference market benchmarks and infra300®

(a) Price returns



(b) Total returns

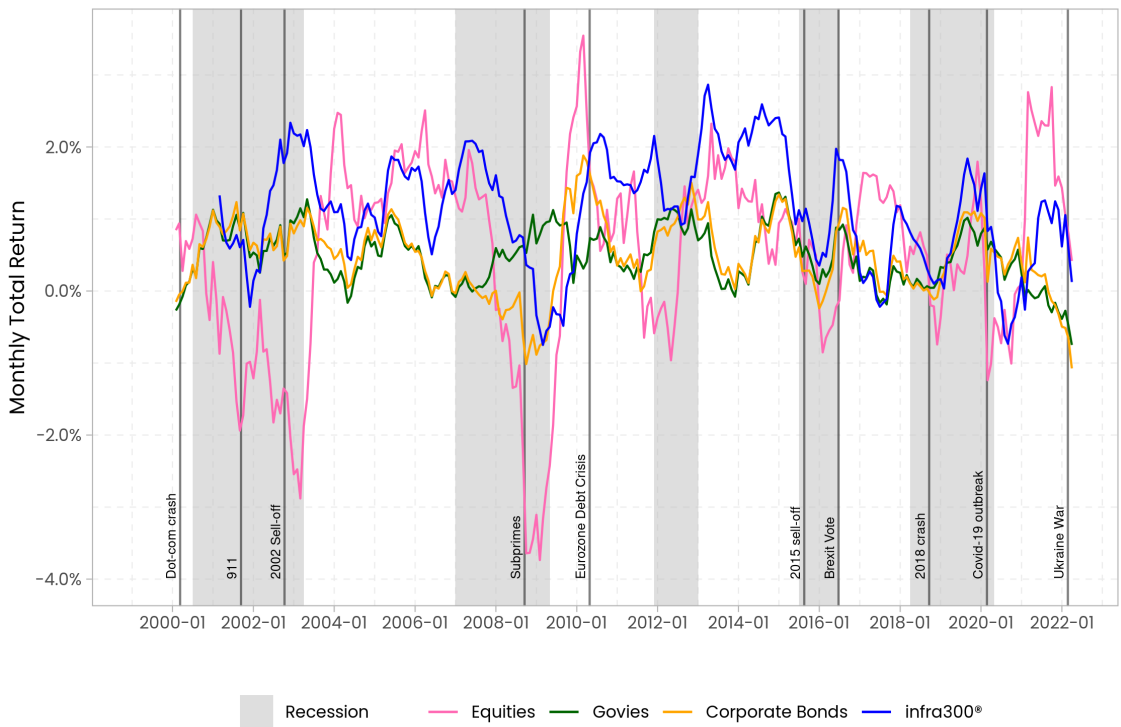


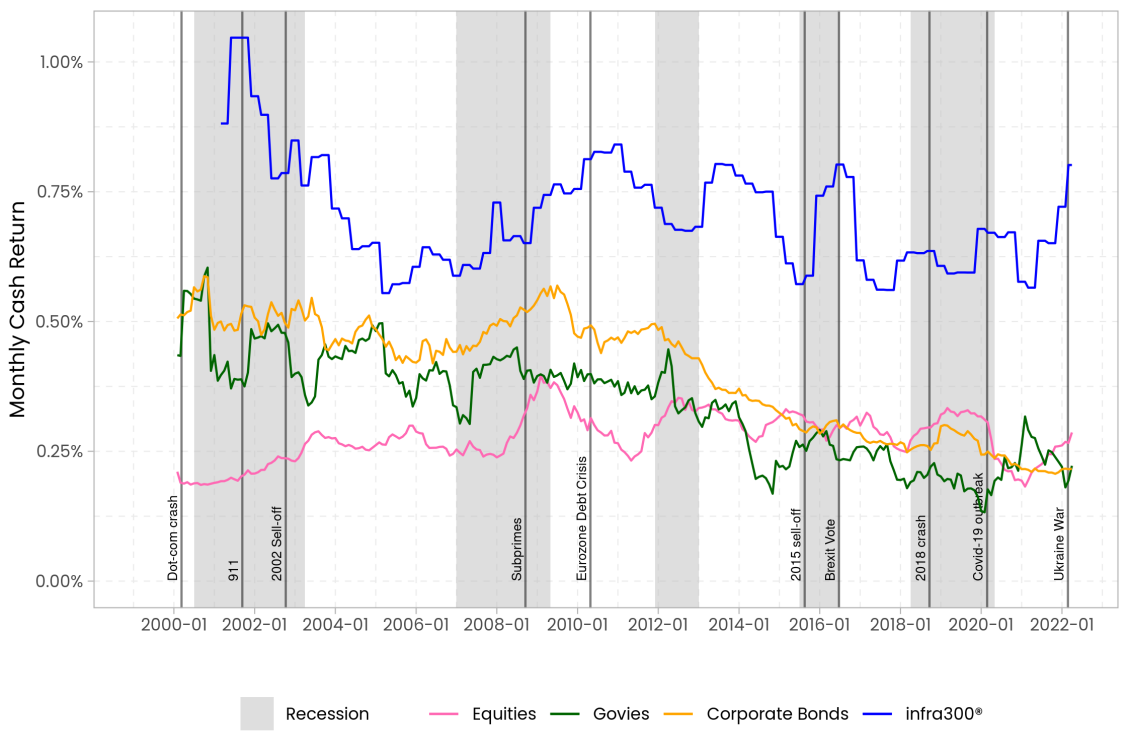
Table 3: Total returns (monthly LCU), 2000-2022, Benchmark Portfolios and Infra300 Index

	Equities	Govies	Corporate Bonds	infra300®
Annualized Return	0.0548	0.0503	0.0493	0.1354
Annualized Std Dev	0.1409	0.0509	0.0612	0.0826
Annualized Sharpe (Rf=1%)	0.3148	0.7838	0.6362	1.5052
monthly Std Dev	0.0407	0.0147	0.0177	0.0238
Skewness	-0.6941	-0.0110	-0.6608	-0.5689
Kurtosis	4.7712	2.9061	5.2433	3.2662
Excess kurtosis	1.7712	-0.0939	2.2433	0.2662
Sample skewness	-0.7017	-0.0111	-0.6680	-0.5753
Sample excess kurtosis	1.8253	-0.0737	2.3061	0.2943

Table 4: Price returns (monthly LCU), 2000-2022, Benchmark Portfolios and Infra300 Index

	Equities	Govies	Corporate Bonds	infra300®
Annualized Return	0.0204	0.0088	0.0002	0.0433
Annualized Std Dev	0.1415	0.0544	0.0608	0.0947
Annualized Sharpe (Rf=1%)	0.0729	-0.0214	-0.1591	0.3481
monthly Std Dev	0.0408	0.0157	0.0176	0.0273
Skewness	-0.6766	-0.0714	-0.6337	-0.4783
Kurtosis	4.7354	3.1042	5.2033	2.7451
Excess kurtosis	1.7354	0.1042	2.2033	-0.2549
Sample skewness	-0.6840	-0.0722	-0.6406	-0.4838
Sample excess kurtosis	1.7889	0.1279	2.2653	-0.2368

Figure 4: 12-Month average yield, reference market benchmarks and infra300®



Source: Datastream, infraMetrics®

a number of financial market and policy shocks start dates.

Casual observation of these charts reveals that the co-movements of infrastructure returns (in blue) with other asset classes change over time and can be either positive or negative.

The performance of infrastructure and bonds can seem strongly related, presumably via the interest rate channel but this is not always the case especially in times of economic contraction.

For instance, we see evidence of higher co-movement with equities in times of recession especially during the first part of the 2000-2003 recession episode (note that large parts of OECD countries came out of recession earlier in 2002), the 2007-2009 recession, as well as the 2012 and 2016 recessions. However, during the 2018-2020 recession period, infrastructure performed well until the end of 2019 and only started to experience lower returns from December 2019 as economic activity bounced back and interest rates increased.

A number of financial shocks lead to very visible co-movements between infrastructure and equities such as the dot-com crash, the subprime crisis and the 2015 sell-off. However, not all financial crises seem to affect the private infrastructure sector. The 2002 sell-off and the Eurozone debt crisis, for instance, do not coincide with large losses in the infra300®, despite their impact on capital markets.

Some policy shocks are also sources of downside for infrastructure, especially the Covid-19 lockdowns, that went on to trigger inflation and interest rate shocks, and the outbreak of the Ukraine war of February 2022. However, events like 9-11 or Brexit do not seem to increase downside risks for infrastructure investors.

Indeed, infrastructure and equities also exhibit minimal and sometimes seemingly negative correlations, especially in periods of economic expansion.

Figure 4 also shows, as we would expect, that cash returns tend to increase during bad times as asset prices fall. This confirms the relative 'stickiness' of dividends (on aggregate) in infrastructure investments, even in bad times. In other words, a portfolio of unlisted infrastructure equity can be expected to continue to deliver an income stream during periods of stress. This is of course not always true at the asset level for which defaults and bankruptcies are always possible and well documented (see for example Garcia et al., 2018).

In order to better document the impact of recession, financial and policy shocks on infrastructure, as proxied by the three capital market benchmarks, in what follows we conduct the following analyses:

1. The next section presents a comparative drawdown analysis;
2. We then examine return correlations and co-moments over time;
3. We examine the role of movements in the yield curve and the equity risk premium in explaining the impact of various shocks on infrastructure investments.

4. Drawdown Analysis

To further document the behaviour of infrastructure investments in times of shock, we consider the maximum drawdown behaviour of the infra300®, i.e., the maximum observed loss or drop in value from a peak to a trough until a new peak is reached, compared to that of listed equities and bonds. We examine whether infrastructure equity drawdowns are more likely during period of capital market drawdowns.

4.1 Drawdown profiles

We show the drawdown profile of the infra300® index and the reference asset classes in tables 5 and 6. On a price return basis, infrastructure with c.7% average drawdown is less exposed to losses than stocks (c.13%), more than government bonds (c.4%), and on a par with corporate bonds. On a total return basis, consistent with table 3, infrastructure sits between stocks and bonds in terms of expected losses.

When it comes to maximum or worst drawdowns, on a price return basis, infrastructure remains the second least-worst asset class with 23% observed maximum loss, behind governments bonds (11%) and ahead of corporates bonds (29%) and equities (50%). On a total return basis, infrastructure retains the second place with (15%) maximum observed loss, behind govies (12%), and ahead of corporate bonds (16%) and equities (47%).

The average length of drawdowns is also the shortest for infrastructure: 11.7 months on a price return basis and 6.2 months on a total return basis. Likewise, average drawdown recovery time (from through to peak) is the shortest on a price return basis for infrastructure and the second shortest on a total return basis, with only government bonds recovering faster on average.

Finally, we look at the Conditional Drawdown at Risk (CDaR) as per Chekhlov et al. (2003). For some value α (here 5%), the CDaR is the mean of the worst $(1-\alpha) \times 100\%$ drawdowns.[1] Hence, the 5% CDaR is the average of the worst 5% drawdowns over a given time period using the average and maximal drawdown as boundaries, thus including the magnitude and duration of drawdowns. In comparison, maximum or worst drawdown measure focuses on a single loss event.

On this measure, which is more robust than the worst drawdown, infrastructure equity maintains its between-equity-and-bonds profiles, with a clear tilt towards bond-like extreme risk characteristics. On aggregate, over the considered period, infrastructure appears more resilient to drawdowns than both equities and bonds.

4.2 Drawdown shocks

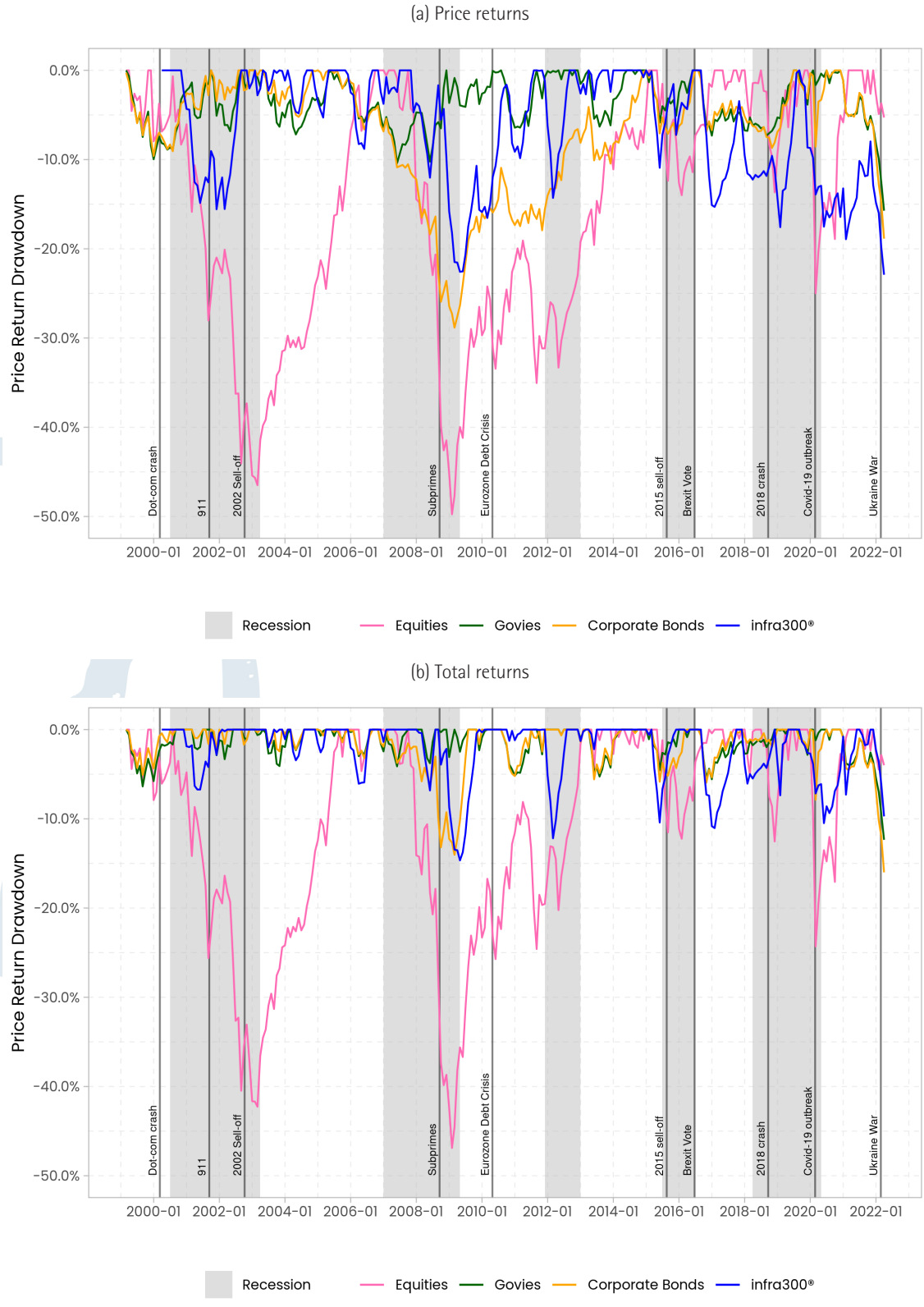
Next, we look at the behaviour of the infra300® during various periods of drawdown in capital markets. Figure 5 shows drawdowns of monthly price and total returns over a period of 22 years. The worst unlisted infrastructure equity drawdowns appear to occur during periods of equity and corporate bond market drawdown and economic recessions.

Tables 7 and 8 show the dates, depth and recovery information for the top 10 drawdowns in each asset class, sorted by depth, for price returns and total returns respectively.

On a price return basis, the infra300®'s two worst drawdowns include the subprime crisis and the October 2019 downturn triggered by higher interest rates that was still unfolding in 2022, as the longest and worst drawdown for this asset

1 - The CDaR family of risk functions is related to the conditional value-at-risk (CVaR) measure.

Figure 5: Return drawdowns for reference asset classes and infra300® index



Source: Datastream, infraMetrics®

Table 5: Drawdown statistics, price returns, 2000-2022

	Equities	Govies	Corporate Bonds	Infra300®
Average Drawdown	0.1287	0.0506	0.0683	0.0749
Worst Drawdown	0.4976	0.1573	0.2884	0.2291
Average Length	18.3571	13.9474	19.2857	11.7895
Average Recovery	11.8571	6.8421	9.5000	4.6842
Conditional Drawdown 5%	0.3896	0.1003	0.1609	0.1833

Table 6: Drawdown statistics, Total returns, 2000-2022

	Equities	Govies	Corporate Bonds	Infra300®
Average Drawdown	0.0745	0.0263	0.0293	0.0462
Worst Drawdown	0.4689	0.1235	0.1600	0.1466
Average Length	8.8148	6.2424	6.3235	6.2308
Average Recovery	5.2963	3.3636	2.8824	3.5385
Conditional Drawdown 5%	0.1665	0.0523	0.0591	0.1073

class. This is due to the higher risk premium, as well as – since the Covid lockdowns – higher interest rates and – in some sectors like transport, especially airports and ports – lower expected cash flows.

Corporate and government bonds were also still going through their latest drawdown period in April 2022, also the worst one in the 22-year period for govies, and the second worst one for corporate bonds. On a total return basis, the current drawdown of the infra300® is only the sixth worse in the last two decades and it only started in January 2022 with the latest spike in interest rates. By comparison, as of May 2022, corporate and government bonds were undergoing their worst total return drawdown since 1999.

Thus, we see that when capital markets are impacted by shocks, these losses often coincide with losses in the private infrastructure market, albeit not perfectly and not always.

There are three possible mechanisms through which capital market drawdown might coincide with drawdown in the private infrastructure portfolio:

1. Cash flows: Recessions that depress asset values in stocks and bond markets also mean lower revenues for certain infrastructure companies especially if they have a merchant business model. Policy shocks like travel bans during the Covid-19 pandemic or sanctions related to the war in Ukraine can also have a significant impact on the cash flows of some infrastructure investments.
2. The equity risk premium: The price of cash flow risk, i.e., the expected excess return of infrastructure investments is a function of investor preferences and is not independent across asset classes. For example, if a financial shock increases the equity risk premium in public equity markets, it is likely to coincide with a high equity risk premium in private asset markets like infrastructure.
3. The yield curve: Whether interest rates vary as a result of macro-economic or macro-prudential causes, all asset values are ultimately impacted by movements in the yield curve, as a function of the investment's duration.

To examine the coincidence of drawdowns between the infra300® and capital markets, we look at return correlations and co-moments in the next section.

Table 7: Price Return drawdown periods for reference asset classes and infra300®

Type	From	Trough	To	Depth	Length	To Trough	Recovery
>40%							
Equities	2007-11-01	2009-02-01	2015-02-01	-0.50	88	16	72
Equities	2000-01-01	2003-03-01	2006-10-01	-0.46	82	39	43
20-30%							
Corporate Bonds	2005-09-01	2009-03-01	2015-01-01	-0.29	113	43	70
Equities	2020-01-01	2020-03-01	2021-03-01	-0.25	15	3	12
infra300®	2019-10-01	2022-04-01	NA	-0.23	32	31	NA
infra300®	2007-12-01	2009-05-01	2011-08-01	-0.23	45	18	27
10-20%							
Corporate Bonds	2021-01-01	2022-04-01	NA	-0.19	17	16	NA
infra300®	2016-10-01	2019-02-01	2019-09-01	-0.18	36	29	7
Govies	2020-08-01	2022-04-01	NA	-0.16	22	21	NA
infra300®	2000-12-01	2001-12-01	2002-09-01	-0.16	22	13	9
infra300®	2011-12-01	2012-03-01	2012-09-01	-0.14	10	4	6
Equities	2015-06-01	2016-02-01	2017-02-01	-0.14	21	9	12
Equities	2018-08-01	2018-12-01	2019-11-01	-0.14	16	5	11
infra300®	2015-02-01	2015-06-01	2016-06-01	-0.11	17	5	12
5-10%							
Govies	2005-07-01	2007-06-01	2008-12-01	-0.10	42	24	18
Govies	1999-04-01	2000-01-01	2001-10-01	-0.10	31	10	21
Corporate Bonds	1999-03-01	2000-01-01	2001-10-01	-0.10	32	11	21
infra300®	2005-12-01	2006-06-01	2006-09-01	-0.09	10	7	3
Corporate Bonds	2016-09-01	2018-11-01	2019-07-01	-0.09	35	27	8
Corporate Bonds	2019-09-01	2020-03-01	2020-07-01	-0.09	11	7	4
Govies	2016-09-01	2018-09-01	2019-07-01	-0.07	35	25	10
Corporate Bonds	2015-02-01	2015-12-01	2016-07-01	-0.07	18	11	7
Govies	2003-06-01	2004-05-01	2005-06-01	-0.07	25	12	13
Govies	2001-11-01	2002-05-01	2002-09-01	-0.07	11	7	4
Equities	1999-05-01	1999-09-01	1999-11-01	-0.07	7	5	2
Govies	2010-09-01	2011-01-01	2011-09-01	-0.06	13	5	8
Govies	2013-05-01	2013-08-01	2014-06-01	-0.06	14	4	10
Equities	2018-02-01	2018-03-01	2018-07-01	-0.06	6	2	4
Govies	2015-02-01	2015-06-01	2016-06-01	-0.06	17	5	12
<5%%							
Equities	2022-01-01	2022-04-01	NA	-0.05	5	4	NA
infra300®	2004-12-01	2005-03-01	2005-05-01	-0.05	6	4	2
Corporate Bonds	2003-06-01	2004-06-01	2004-11-01	-0.05	18	13	5
infra300®	2004-03-01	2004-06-01	2004-09-01	-0.05	7	4	3
Equities	2007-06-01	2007-08-01	2007-10-01	-0.04	5	3	2
Govies	2009-01-01	2009-07-01	2010-08-01	-0.04	20	7	13
infra300®	2006-12-01	2007-01-01	2007-07-01	-0.04	8	2	6
Corporate Bonds	2001-11-01	2001-12-01	2002-08-01	-0.03	10	2	8
Equities	2021-11-01	2021-11-01	2021-12-01	-0.03	2	1	1
Corporate Bonds	2002-10-01	2002-10-01	2002-12-01	-0.02	3	1	2
Corporate Bonds	2005-02-01	2005-03-01	2005-05-01	-0.01	4	2	2

Table 8: Total returns drawdown periods for reference asset classes and infra300®

Type	From	Trough	To	Depth	Length	To Trough	Recovery
>40%							
Equities	2007-11-01	2009-02-01	2013-02-01	-0.47	64	16	48
Equities	2000-09-01	2003-03-01	2005-09-01	-0.42	61	31	30
20-30%							
Equities	2020-01-01	2020-03-01	2021-03-01	-0.24	15	3	12
10-20%							
Corporate Bonds	2021-01-01	2022-04-01	NA	-0.16	17	16	NA
infra300®	2008-10-01	2009-05-01	2009-12-01	-0.15	15	8	7
Corporate Bonds	2006-12-01	2009-03-01	2009-08-01	-0.14	33	28	5
Equities	2018-08-01	2018-12-01	2019-04-01	-0.13	9	5	4
Govies	2021-01-01	2022-04-01	NA	-0.12	17	16	NA
Equities	2015-06-01	2016-02-01	2016-12-01	-0.12	19	9	10
infra300®	2012-01-01	2012-03-01	2012-08-01	-0.12	8	3	5
infra300®	2016-10-01	2017-02-01	2017-10-01	-0.11	13	5	8
infra300®	2019-10-01	2020-06-01	2021-06-01	-0.10	21	9	12
infra300®	2015-04-01	2015-06-01	2015-12-01	-0.10	9	3	6
5-10%							
infra300®	2022-01-01	2022-04-01	NA	-0.10	5	4	NA
Equities	2000-01-01	2000-01-01	2000-08-01	-0.08	8	1	7
Corporate Bonds	2020-02-01	2020-03-01	2020-07-01	-0.08	6	2	4
infra300®	2019-01-01	2019-02-01	2019-05-01	-0.07	5	2	3
infra300®	2008-02-01	2008-06-01	2008-08-01	-0.07	7	5	2
infra300®	2001-01-01	2001-06-01	2002-02-01	-0.07	14	6	8
Govies	1999-04-01	1999-09-01	2000-09-01	-0.06	18	6	12
infra300®	2006-01-01	2006-04-01	2006-08-01	-0.06	8	4	4
Corporate Bonds	2016-09-01	2016-11-01	2017-12-01	-0.06	16	3	13
Corporate Bonds	2015-04-01	2015-06-01	2016-04-01	-0.06	13	3	10
Equities	1999-05-01	1999-09-01	1999-11-01	-0.06	7	5	2
Corporate Bonds	2013-05-01	2013-06-01	2014-04-01	-0.06	12	2	10
Govies	2016-09-01	2017-01-01	2018-12-01	-0.06	28	5	23
Govies	2013-05-01	2013-08-01	2014-04-01	-0.05	12	4	8
Equities	2018-02-01	2018-03-01	2018-05-01	-0.05	4	2	2
Corporate Bonds	2010-09-01	2011-01-01	2011-07-01	-0.05	11	5	6
Govies	2010-09-01	2011-01-01	2011-08-01	-0.05	12	5	7
Corporate Bonds	1999-04-01	1999-09-01	2000-09-01	-0.05	18	6	12
Equities	2006-05-01	2006-05-01	2006-09-01	-0.05	5	1	4
<5%%							
Govies	2015-04-01	2015-06-01	2016-01-01	-0.05	10	3	7
Equities	2022-01-01	2022-02-01	NA	-0.04	5	2	NA
Govies	2006-12-01	2007-06-01	2007-10-01	-0.04	11	7	4
Govies	2003-06-01	2003-11-01	2004-03-01	-0.04	10	6	4
Govies	2008-04-01	2008-06-01	2008-08-01	-0.04	5	3	2
Govies	2001-11-01	2002-03-01	2002-06-01	-0.03	8	5	3
Corporate Bonds	2006-01-01	2006-06-01	2006-10-01	-0.03	10	6	4
Corporate Bonds	2011-11-01	2011-11-01	2011-12-01	-0.02	2	1	1

5. Return Correlation Analysis

In this section, we first examine the return correlations of unlisted infrastructure equity with capital markets over time. Correlations are an expression of the covariance of returns i.e., whether mean infrastructure returns tend to covary more with markets in different periods. Next, we look at higher co-moments of returns: co-skewness and co-kurtosis, that reflect the tendency of multiple asset classes to experience extreme returns at the same time.

5.1 Return correlations

Figures 6 shows the correlation of 12-month average monthly returns between unlisted infrastructure and the reference asset classes over a 22 year period, in local currency. All correlations are highly statistically significant. On a price return basis, infrastructure has a higher correlation with corporate bonds and equities (above 30%) and a lower correlation with government bonds (c.20%). On a total return basis, infrastructure correlations with government bonds are the highest (c.40%), followed by corporate bonds and equities. This confirms that the co-movement of infrastructure with markets is rather different whether one takes the cash yield into account or not. To understand the impact of downturns purely on asset prices, price return correlations provide a more direct comparison.

Next, Figure 7 shows the 60-month (five-year) rolling correlations of monthly returns between the infra300® index and the three reference asset classes. We see that on both a price and total return basis, monthly return correlations are high and positive with bonds. However, they tend to decline during recessions and after financial shocks such as the subprime crash or the start of the 2015 or 2018 sell-offs. Conversely, return correlations increase during period of economic expansions or inflationary shocks like the start of Ukraine conflict.

Correlations with equities also follow a different pattern: on average over the entire period, monthly return correlations are not statistically different from zero because they change sign several times. The correlation between the infra300® and equities increases sharply in times of financial stress, especially the subprime crisis, but also policy shocks like the Brexit vote and the Covid-19 lockdowns. Such shocks coincide with a change of sign in correlations, which turn positive before declining over several years until they return to zero or negative territory.

In all likelihood, a combination of co-movements in equity risk premia, corporate credit spreads and the yield curve is driving correlation dynamics between unlisted infrastructure equity. Before looking at these, we report the higher-order return co-movements of the infra300® with capital markets in the next section.

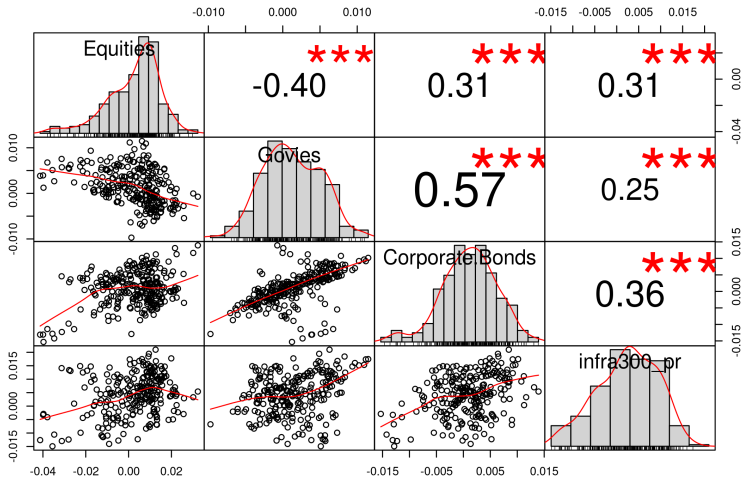
5.2 Return Co-movements

The third and fourth moments of the distribution of returns are known as its skewness and kurtosis and characterise its shape. High skewness is the result of extreme asymmetric positive or negative returns (far from the mean), while high positive excess kurtosis a.k.a. a leptokurtic return distribution, indicate a flatter shape and 'fat tails'. This also contributes to extreme risk.

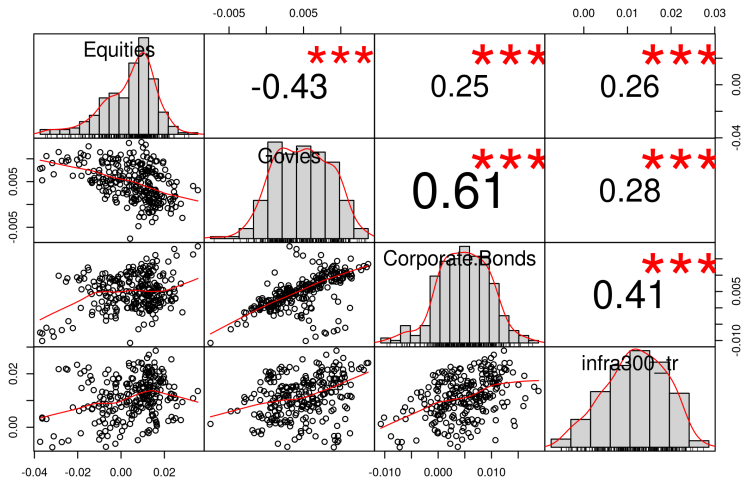
In turn, coskewness and cokurtosis denote the tendency of two distributions to exhibit extreme values at the same time, and provide a measure of co-dependence in extreme or crisis scenarios. Figures 8 and 9 show the 60-month rolling coskewness and cokurtosis of the infra300® index with each of the reference asset classes.

Figure 6: Correlations of 12-month average monthly returns – reference market benchmarks and infra300® index, 2000-2022

(a) Price returns



(b) Total returns



Source: Datastream, infraMetrics®

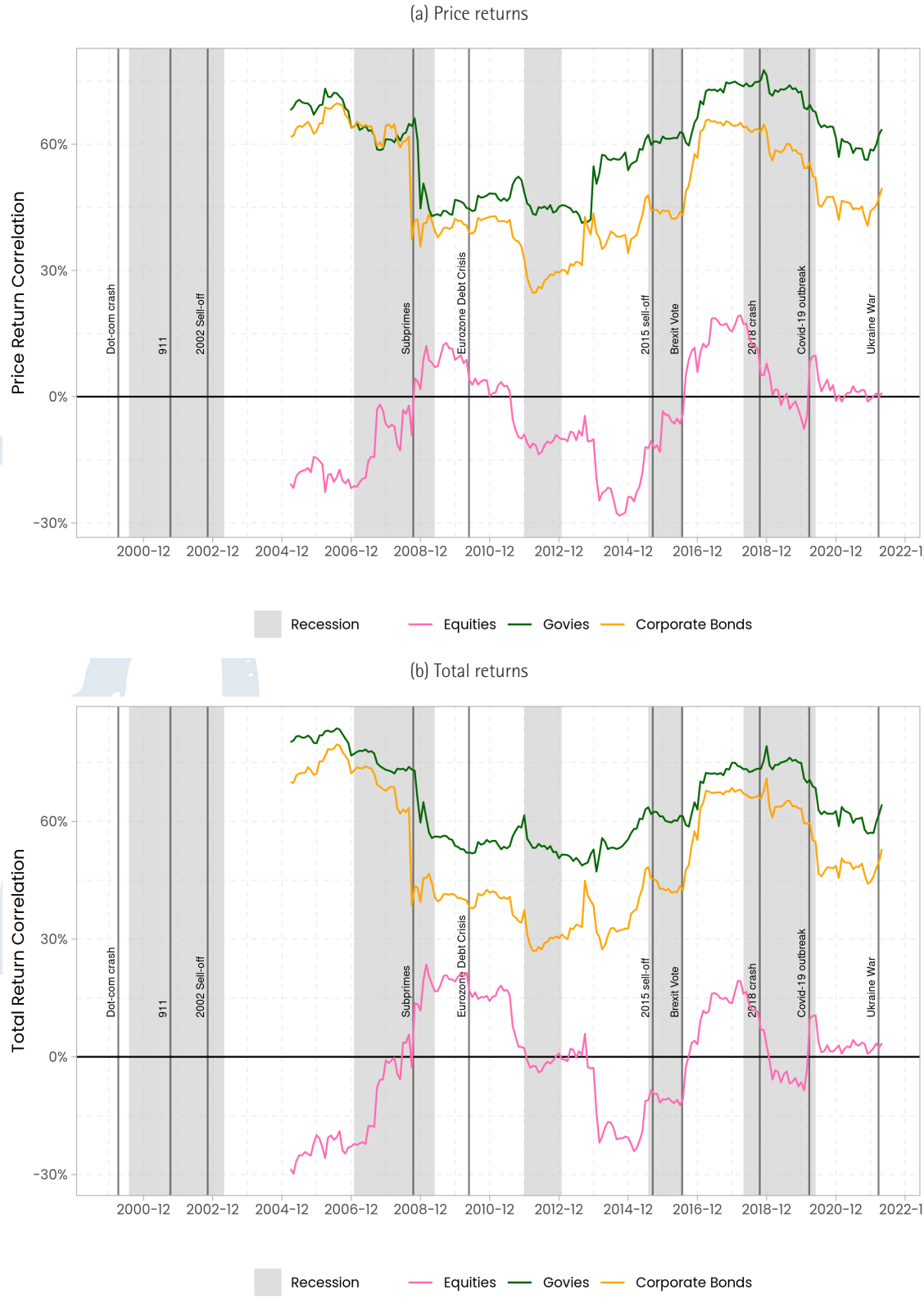
Table 9: Price return co-moment beta of reference benchmarks with infra300®

	BetaCovariance	BetaCoSkewness	BetaCoKurtosis
Equities	-0.0354	0.0829	0.0451
Govies	1.0735	11.2642	1.0029
Corporate Bonds	0.7629	0.5093	0.4529

Table 10: Total return co-moment beta of reference benchmarks with infra300®

	BetaCovariance	BetaCoSkewness	BetaCoKurtosis
Equities	-0.0130	0.1499	0.0533
Govies	1.0722	62.6169	1.0199
Corporate Bonds	0.7033	0.5992	0.4408

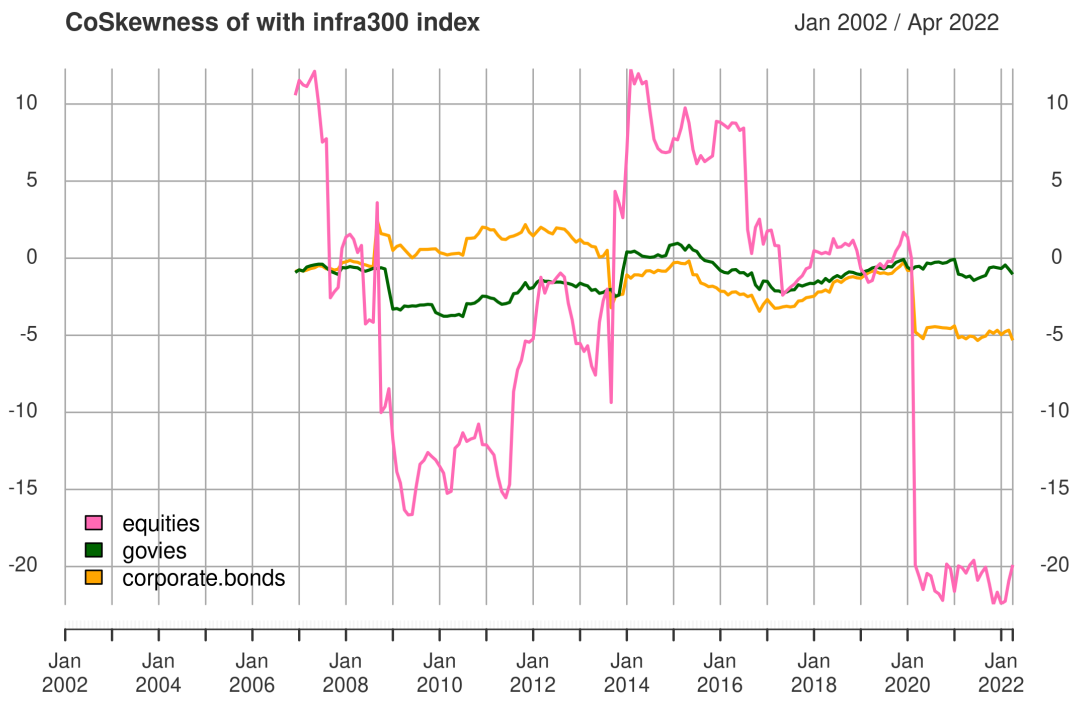
Figure 7: 60-month rolling correlations of returns between reference market benchmarks and infra300®



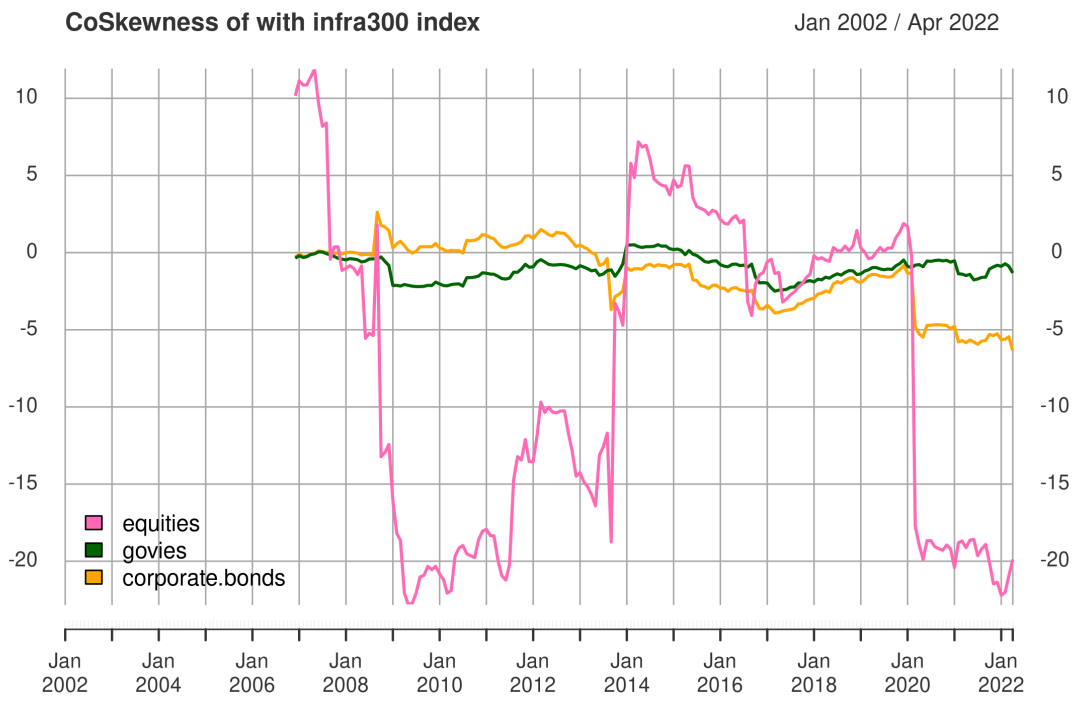
Source: Datastream, infraMetrics®

Figure 8: 60-month rolling coskewness of infra300® index with capital markets

(a) Price returns



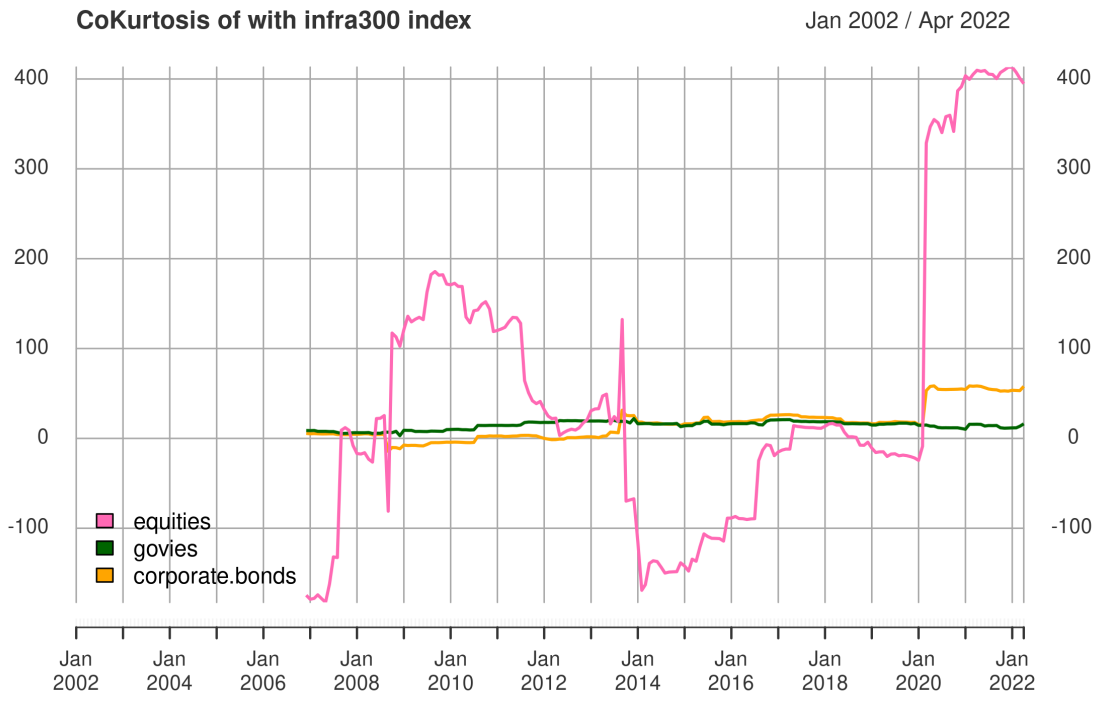
(b) Total returns



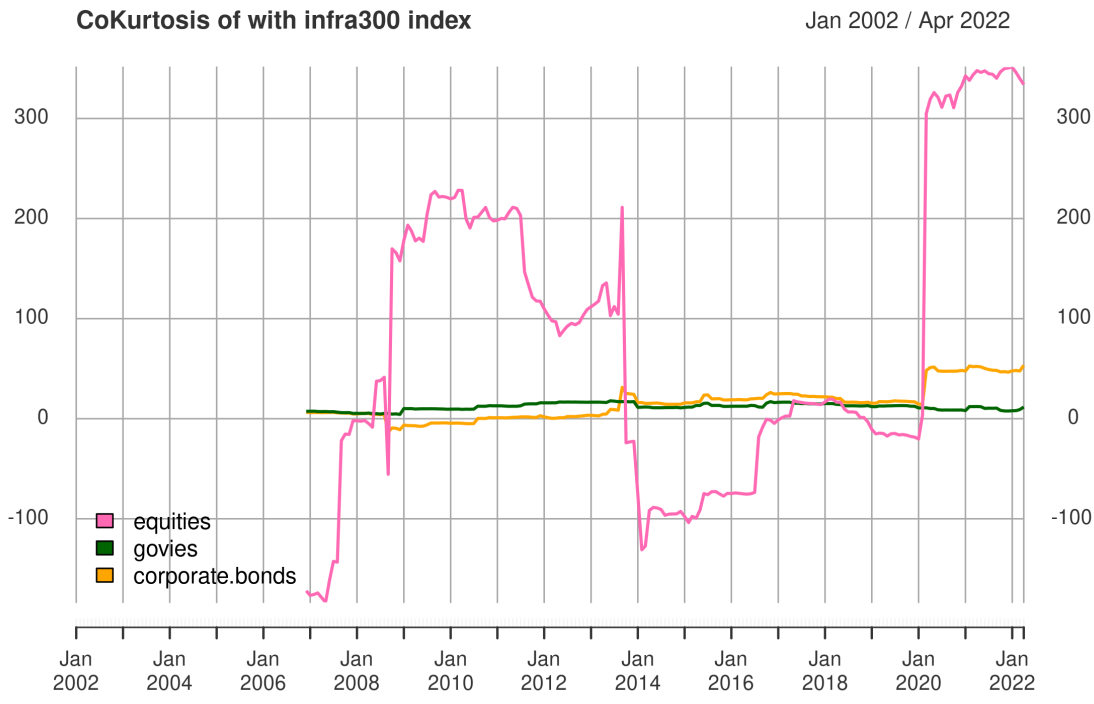
Source: Datastream, infraMetrics®

Figure 9: 60-month rolling cokurtosis of infra300® index with capital markets

(a) Price returns



(b) Total returns



Source: Datastream, infraMetrics®

Coskewness takes the same sign as extreme returns: positive co-skewness indicates that both asset classes are likely to simultaneously exhibit extreme positive returns and vice versa. We see that the subprime crisis in particular triggers a period during which unlisted infrastructure and equities share extreme risk characteristics, at least until 2012. From 2014 to 2017, a period of exceptional performance for unlisted infrastructure, the coskewness of the infra300® and equities is positive until it drops to about zero in 2017. In March 2020, the Covid-19 shock triggers another period of negative coskewness between unlisted infrastructure equity and listed equities.

The cokurtosis of the infra300® with equities tells a similar story. Here, high kurtosis and cokurtosis indicates a 'flatter' distribution and fatter tails. The same pattern is visible, with extreme risk coincidence triggered by certain financial or policy shocks. We note that not all shocks trigger changes of co-moment regimes. These shifts are indicative of not only in the changes in the price of but also the exposure of investment to risk.

Turning to corporate bonds, they exhibit similar but considerably lower coskewness and cokurtosis with infrastructure than equities do. The shift in co-moment regime triggered by the Covid-19 shock is notable because the impact of the subprime shock on the likelihood of extreme risk in both infrastructure and corporate bonds was much smaller and short-lived.

When it comes to government bonds, their extreme co-movements with infrastructure are much smaller in comparison. Thus, while infrastructure and government bonds are highly correlated through the impact of the yield curve on asset values, the two asset classes do not share extreme risk characteristics.

Finally, we look at the link between each asset class in terms of extreme risk. Indeed, return co-moments like covariance, coskewness, and cokurtosis do not allow measuring the marginal impact of one asset class on another.

Martellini and Ziemann (2007) have shows that higher moment betas can provide estimates of how the risk of a benchmark asset class is impacted by adding a second asset class to the portfolio. In the portfolio diversification theorem, adding a test asset class to a benchmark reduces the portfolio's variance if the second-order beta of the asset with respect to the portfolio is less than one. The same can me shown for the third and fourth moments of the return distribution. Higher moment betas thus provide measures of the diversification potential of an asset (see Martellini and Ziemann, 2007, for details).

A beta greater than one indicates that no diversification benefits should be expected from the introduction of that asset into the portfolio. Conversely, a beta of less than one indicates that adding the test asset reduces the resulting portfolio's volatility and extreme risk. The lower the beta, the higher the diversification effect on extreme risks.[1]

Tables 9 and 10 shows the co-moment betas defined in the literature for price and total returns respectively. We see that adding unlisted infrastructure equity to an equity or corporate bond portfolio does have diversification benefits including extreme risk diversification. The reverse is true for government bonds: unsurprisingly infrastructure adds total risk to a public bond portfolio.

Thus, unlisted infrastructure exhibits correlations with other asset classes both in terms of mean returns and extreme returns. Mean returns are correlated with bonds but extreme returns

1 - The addition of a small fraction of a new asset to a portfolio leads to a decrease in the portfolio's second moment (respectively, an increase in the portfolio's third moment and a decrease in the portfolio's fourth moment) if and only if the second moment (respectively, the third moment and fourth moment) beta is less than one. If the skewness of the portfolio is negative, we would expect an increase in portfolio skewness when the third moment beta is lower than one. When the skewness of the portfolio is positive, then the condition is that the third moment beta is greater, as opposed to lower, than one.

correlate with equities during period of financial and economic stress. In the next section, we return to the role of the equity risk premium and the yield curve in driving return correlations between these asset classes.

Next, we examine in more details the common factors that can explain the coincidence of large losses in capital markets and private infrastructure equity with a focus on the two main components of the discount rates: interest rates and the equity risk premium.

6. Discount rate shock analysis

Until now, we have empirically examined how the unlisted infrastructure asset class and capital markets co-vary in terms of risk adjusted returns and drawdowns, including the likelihood of them facing extreme losses at the same time in periods of economic or financial stress. In this section, we look at the role played by the equity risk premium and interest rates in the coincidence of these losses.

6.1 Risk premium shocks

The equity risk premium plays a key role in the performance of an asset class during a shock. It is the aggregate price of the risks of the cash flows (dividends) that the owners of a company expect to receive in the future. It combines the inherent uncertainty of future economic economic activities, which underpins the ability of firms to pay dividends, with investors' aversion for risk to form a price i.e. a risk premium. This premium is also the embodiment of investors' expected (excess) returns: the higher it is, the lower the bid price for an asset and vice versa: a lower risk premium indicates that investors are willing to pay a higher price because they value holding the asset in question and thus accept a lower return.

In previous sections, we have seen that in times of stress, in particular the subprime crisis and the onset of the Covid-19 pandemic, unlisted infrastructure equity and listed equity share some of their tail risk i.e. they incur higher losses at the same time. An obvious place to look for the source of this coincidence of losses is the risk premium.

Indeed, if investors become more averse to risk in public equities after or during a shock, they are likely to also develope higher risk aversion to the risks of unlisted equity, especially illiquid assets like infrastructure.

We source source the unlisted infrastructure equity risk premium from infraMetrics and the risk premium for the four listed equity markets mentioned earlier from Datastream (see Appendix). For equities we create a weighted risk premium using the same geographic weights we used earlier to create an equity market proxy that has the same geographic characteristics as the unlisted infrastructure universe.

Next, we create a measure of shocks to the infrastructure and equities risk premiua sourced from infraMetrics and Datastream respectively: we take the one-month difference in the risk premium and compute its six-month moving average. Figure 10 shows the distribution (10a) and time series (10b) of these shocks to the risk premium that applies to either unlisted infrastructure or listed equities.

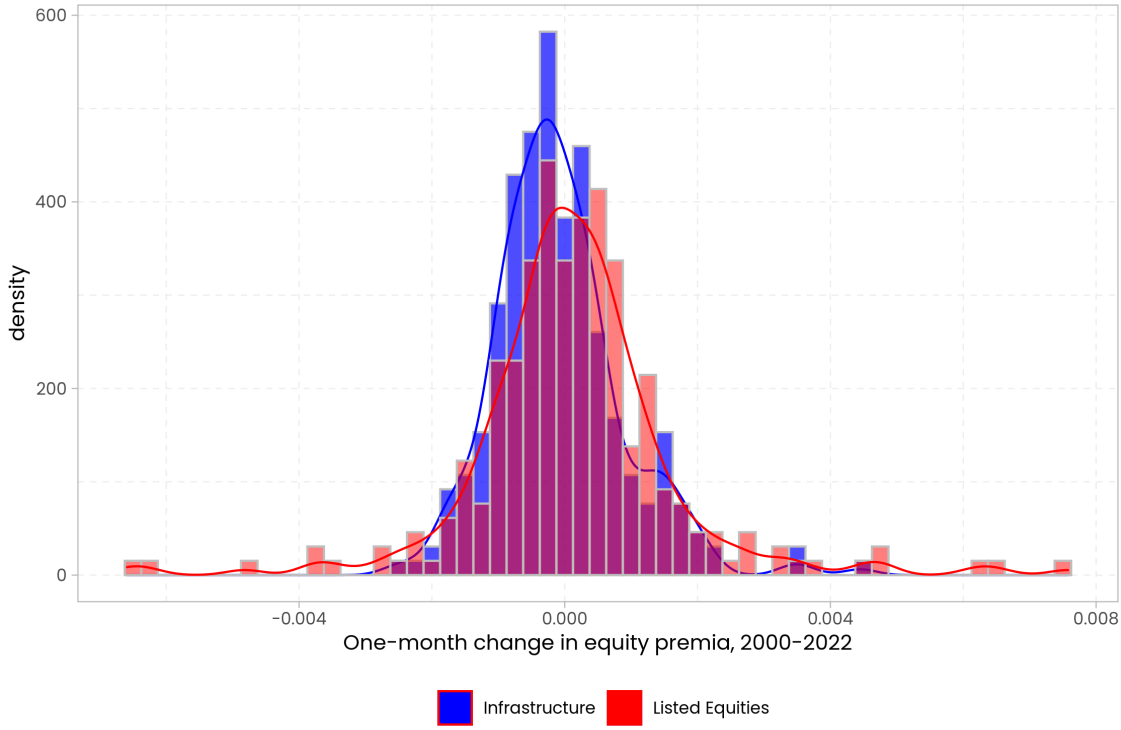
Listed equities exhibit a slightly higher level of shocks to the risk premium on average and also more extreme shocks than unlisted infrastructure. Still, positive shocks to the unlisted infrastructure equity risk premium are not negligible at all. Figure 10 also suggests that shocks to the listed equities and unlisted infrastructure equity risk premia are not always synchronised.

The rolling correlation between shocks to the relevant equity risk premium and the returns of either listed equities or unlisted infrastructure are shown on figure 11 for price returns (11a) and total returns (11b). The correlations are negative: higher positive shocks to the risk premium of either listed equities or unlisted infrastructure equities coincides with a negative return (it increases the discount rate).

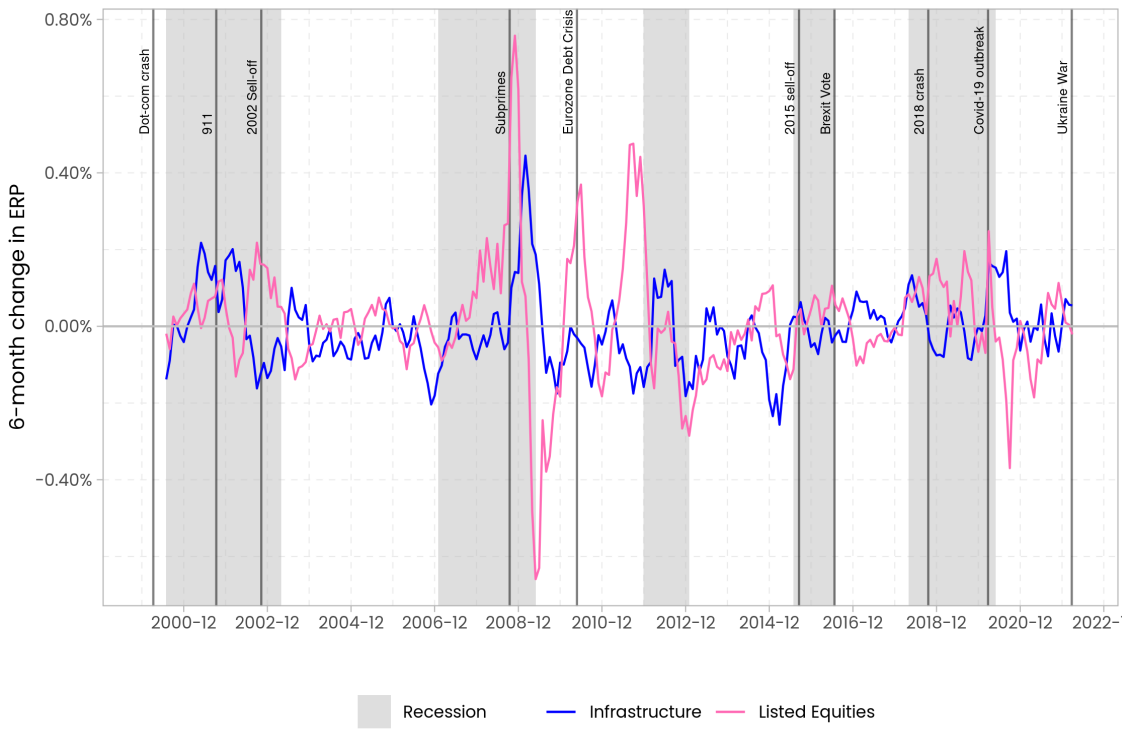
Equities and infrastructure have different returns and different risk premia but they follow a

Figure 10: Shocks to the unlisted infrastructure equity risk premium, 1999-2022

(a) Histogram of monthly change in equity risk premium



(b) Six-month moving average change in ERP



Source: Datastream, infraMetrics®

comparable pattern in terms of the relationship between the shocks to their risk premia and returns. These correlations increase (become more negative) in time of stress such as the subprime crisis or Covid lockdowns. This explains why equities and infrastructure have a highly negative coskewness and highly positive cokurtosis of returns at the time of these events, as we showed in the previous section.

6.2 Interest rate shocks

To look at the role of changes in interest rates as a driver of the return co-moments in private infrastructure and capital markets, we compute the monthly change in the 10-year government bond yield. Figure 12 shows the distribution of interest rate shocks in the four key regions that we defined earlier to build capital market benchmarks, between 1999 and 2022. We see that the monthly change in yield exhibits comparable distributions. Thus, we define interest rate shocks as the six-month rolling average change in 10-year bond yields, which is shown on figure 12b.

Next, figure 13 shows the 60-month rolling correlations between monthly returns and interest rate shocks as defined above for price (13a) and total returns (13b). We see that:

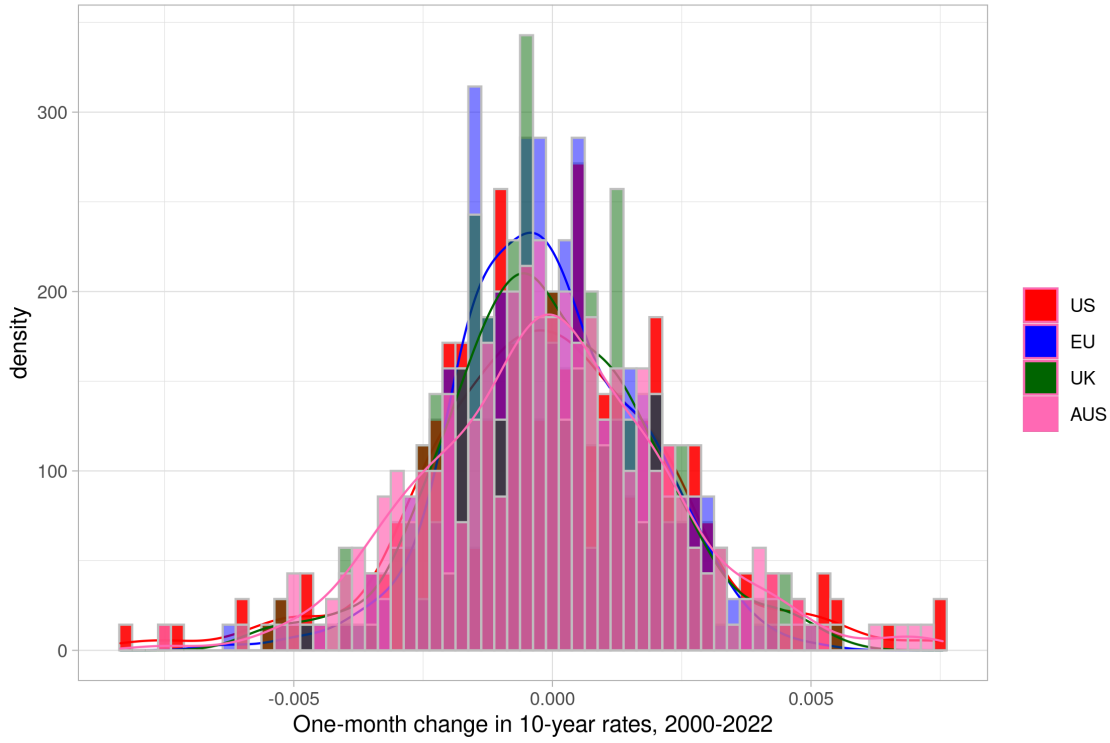
- Government bond returns (green line) are always negatively correlated with interest rate shocks i.e., higher rates always mean lower bond returns since higher discount rates decrease the net asset value of asset with fixed cash flows.
- Listed equity returns (pink line) are positively correlated with rate shocks until 2017 i.e. higher rates signal positive economic prospects and higher future cash flows; this more than offsets the increase in the discount rate implied by higher rates. After 2017, the positive correlation disappears. Unconventional monetary policies mean that rates are very low, hence asset values become more sensitive to increases in rates (which dominate cash flow effects). Moreover rate increases from the lower-zero bound after 2017 are not necessarily a signal of economic growth.
- Corporate bond returns (orange line) like government bonds tend to have a negative correlation with rate shocks. However, between 2008 and 2013 the correlation becomes positive i.e. higher 10-year bond yields coincides with higher corporate bond returns. This is less straightforward to interpret: during that period corporate bonds go through a period of yield compression due to high levels of demand for these instruments. Excess demand is such that prices increase more during that period than they decrease whenever rates increase. This excess demand eventually disappears after 2014.
- Unlisted infrastructure equity returns (blue line) follow a similar pattern to corporate bonds during the same time period: in general the value of infrastructure investments is based on long-dated cash flows and higher rates that tend to increase discount rates that also decrease net asset values. This is very much the case in 2022: a significant rate shock is associated with a large drop in returns for all asset classes, even equities. Indeed, the rise in rates is inflation-driven and the real value of long-term cash flows is also more highly discounted. However, during the 2008-2014 period, unlisted infrastructure goes through a similar period of excess demand combined with low policy rates, meaning that the correlation between rate shocks and returns becomes positive during that period.

Figure 11: 60-month rolling correlations of returns with equity risk premium shocks

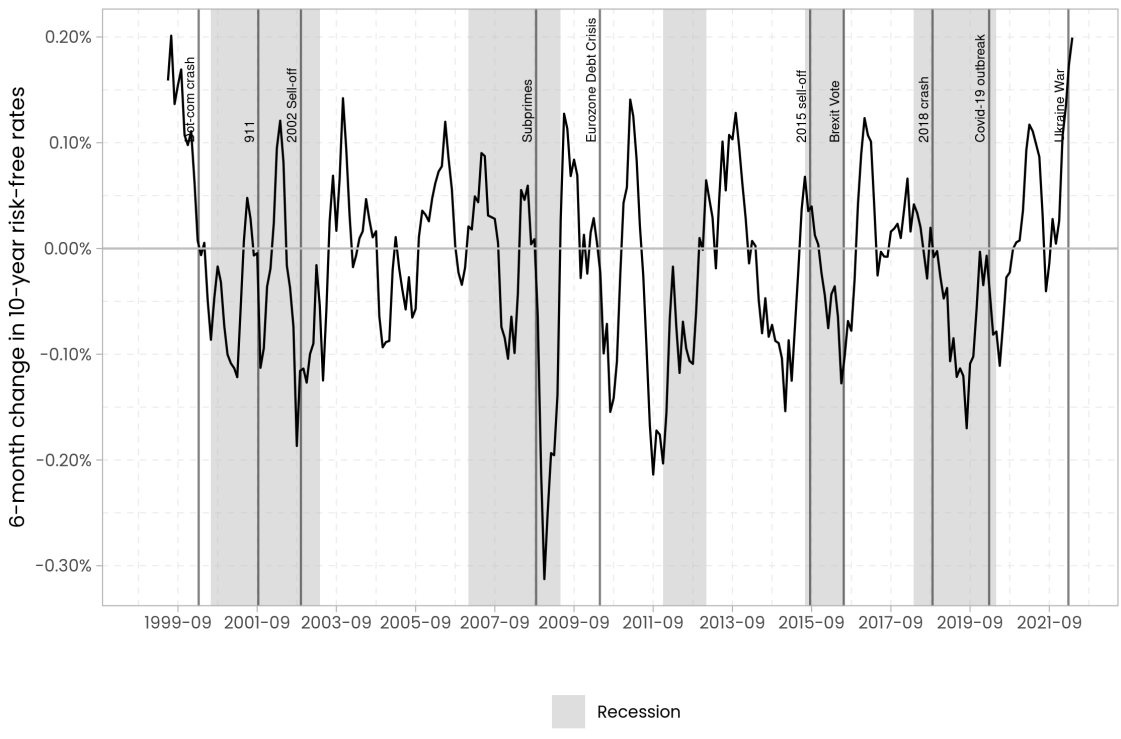
Source: Datastream, infraMetrics®

Figure 12: Shocks to 10-year risk-free yields, US, EU, UK, Australia, 1999-2022

(a) Histogram of monthly change in yields



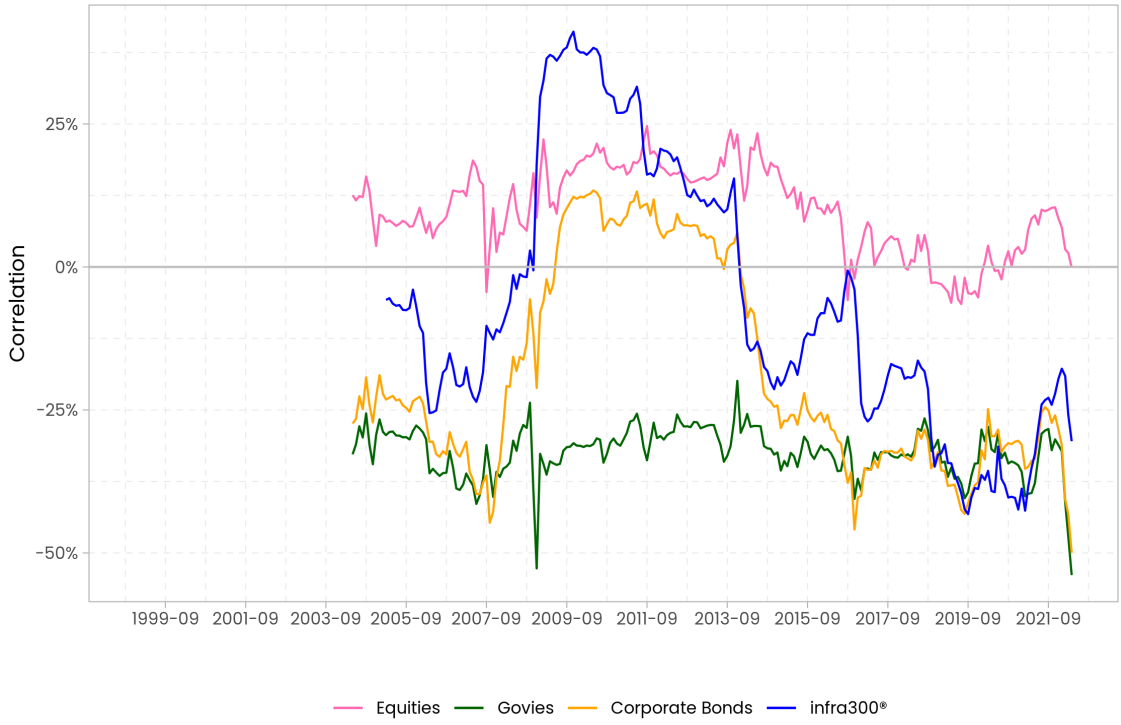
(b) Six-month moving average change in yields



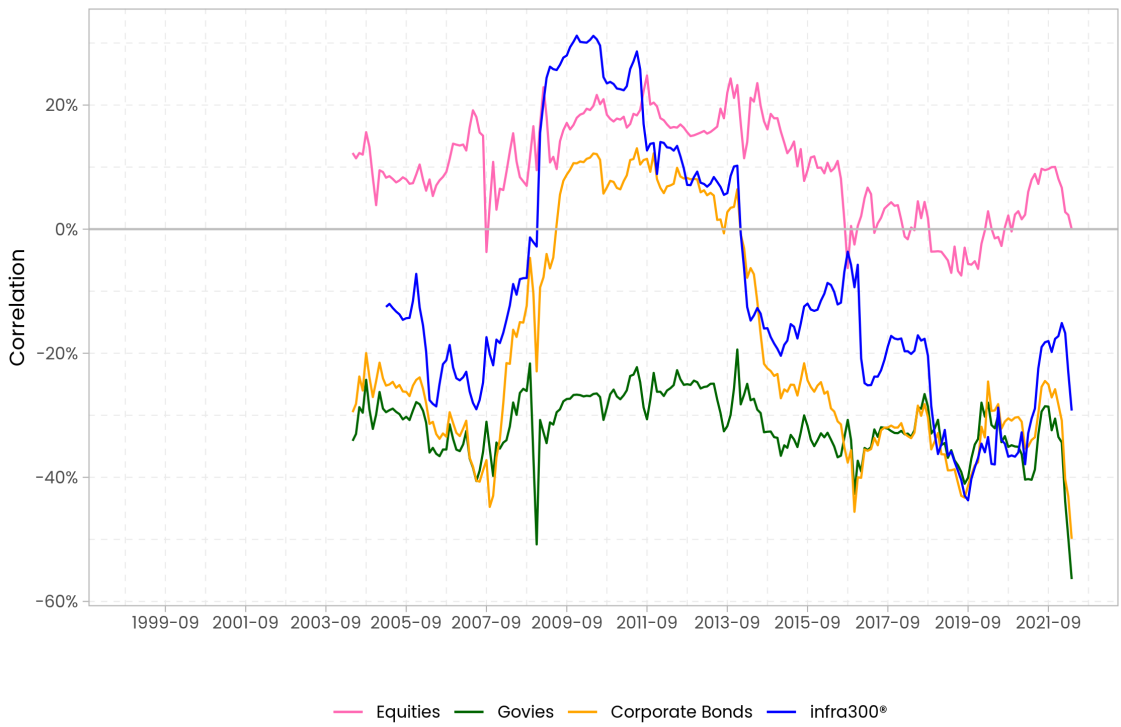
Source: infraMetrics®

Figure 13: 60-month rolling correlations of returns with interest rate shocks

(a) Price returns



(b) Total returns



Source: Datastream, infraMetrics®

7. Comparative Sector Analysis

From the analysis above, we see that the drivers of returns co-movements for unlisted infrastructure investments and capital markets are first and foremost a matter of joint exposure to interest rates and equity risk. However, even when comparing shocks only to price returns, cash flows still play an important role in determining the tendency of infrastructure investment to co-move with capital markets returns.

Indeed, the cash flow profile of each infrastructure company can compound or counteract the combined effects of the yield curve and risk premium, in particular if future cash flows are fixed, as in the case of contracted infrastructure, or by contrast exhibit a certain potential for growth, as is the case for merchant and – to some extent – regulated assets.

Different types of infrastructure companies also have different lifecycles and investment horizons. For instance, utilities are very long-lived, while social or wind power projects typicaly have a finite investment life of 20-40 years. It follows that there are sector-specific exposures to duration risk. Finally, different sectors tend to correspond to different business models e.g., social infrastructure is almost always contracted, while utilities are typically regulated, etc. As a result the average equity risk premium also differs between sectors, since these create different exposures to the factors that drive the risk premium of equity.

In this section, we consider the behaviour of three segments of the unlisted infrastructure equity universe as defined by the TICCS® taxonomy of infrastructure investments, namely Social Infrastructure (IC30), Network Utilities (IC80) and Transport Companies (IC60). We consider only the price returns of each infrastructure equity segment compared with the price returns in capital markets, as this is the most relevant outcome in the event of pricing shocks. We know that cash yields are systematically higher in infrastructure, hence total returns are less directly comparable with shocks in capital markets than price returns.

Social Infrastructure (IC30) equity investments are typically made in single purpose vehicles with a long repayment horizon and a pre-agreed revenue or rent to be paid by a public sector client to the infrastructure company providing a infrastructure service with certain output specifications. This rent can be indexed, as is the case with UK 'private finance initiatives', or not, as in the case of French 'contrats de partenariat'. These equity investments in Social Infrastructure thus resemble an amortising bond with risky coupons; payouts can vary in size and timing as a function of the operational performance of the company, and at the end of the contract the stream of cash flows stops – there is no terminal value. As a result, investors in Social Infrastructure are exposed to duration, but while they cannot expect much growth in the revenues, since the volume and pricing of the service provided are agreed at the onset of the contract, the absence of any re-investment opportunity should lead to increasing dividend distributions.

Network Utilities (IC80) have extremely long lives and, to some extent, can be considered perpetuities. Unlike Social Infrastructure, they also have some growth potential: they often engage in network expansion programmes thus acquiring new customers, and benefit from some pricing power or cost pass-through mechanisms in the case of regulated utilities. Hence, they are likely to have higher revenue growth than Social Infrastructure and other contracted infras-

tructure projects. However, they are more likely to retain earnings to be in a position to self-finance future capital investments. Their dividend growth would then be lower than their revenu growth.

While utilities are also exposed to duration risk, this potential growth of future cash flows can have a countervailing effect i.e., in bond parlance, Network Utilities have a 'higher convexity' than Social Infrastructure. In other words, their cash flow profile makes them less vulnerable to increases in the discount rate.

Finally, the Transport Sector (IC60) is a mix of contracted, regulated and merchant infrastructure businesses, typically with a long duration but also more potential for cash flow growth than Network Utilities in the case of merchant assets. Transport Companies are more exposed to changes in the macroeconomic cycle; the elasticity of demand for transport services in the event of sudden changes in economic activity is typically higher than that of network utilities. We can thus expect higher convexity – lower sensitivity to changes in the yield curve – but greater co-movements with the equity risk premium in times of macro-shocks.

7.1 Drawdowns

Table 12 shows the drawdown statistics for each of the three segments. All infrastructure sectors have lower drawdown characteristics than equities but there are clear differences between them, reflecting their individual investment characteristics.

Table 11 shows the realised revenue and dividend growth, duration and convexity[1] of the three segments. Higher convexity indicates that asset prices are less sensitive to changes in the discount rate. We note that infarstructure investments have higher convexity than bonds (Goverment bond indices have a convexity of c.100, and corporate bond indices of c.120), which is an indication of their relatively better ability to hedge interest rate risk.

As expected, Social Infrastructure projects have a lower realised revenue and dividend growth for the 2011-2022 period. Transport and Network Utilities exhibit both higher revenue and dividend growth over the period.

Social Infrastructure and Utilities have, perhaps counter-intuitively, the worst drawdowns of the three segments, while Transport has both the shortest drawdowns and recovers the fastest when compared to other infrastructure segments.

7.2 Return sensitivity to rate and risk premium shocks

Next, figures 16, 14 and 15 show the rolling correlations of price returns with interest rates and equity premium shocks for Transport Utilities, Social Infrastructure and Network Utilities, respectively.

Social Infrastructure has the strongest correlation with interest rate shocks, and is almost identical to them after 2016. In comparison, Utility price returns are less correlated with interest shocks and Transportation price returns even less so. The reverse is true for price return correlations with shocks to the equity risk premium. Social Infrastructure returns are relatively less correlated with such shocks, while Transport and Utilities exhibit higher negative correlations to price returns and equity premium shocks.

7.3 Extreme values & co-moments

Finally, figures 17, 18 and 19 show the co-skewness and co-kurtosis with bond and equity price returns of Social Infrastructure, Network Utilities and Transport, respectively. These measures are unit-less and represent a score of the tendency to exhibit extreme values at the same time.

1 - Convexity is the second derivative of asset prices relative to changes in yield; it can be thought of as the change of duration given a 1% change in yield.

Table 11: Typical Duration, Convexity, Revenue and Dividend Growth, 2000-2021

	Social Infrastructure	Transport	Utilities
Mean Duration (%)	9.70	9.31	8.86
Mean Convexity	164	203	162
Mean Realised Revenue growth* (%)	5.58	8.78	9.15
Mean Realised Dividend growth* (%)	12.20	20.33	22.83

* excludes outliers higher than 1000% Source: infraMetrics. Sample of c.330 firms.

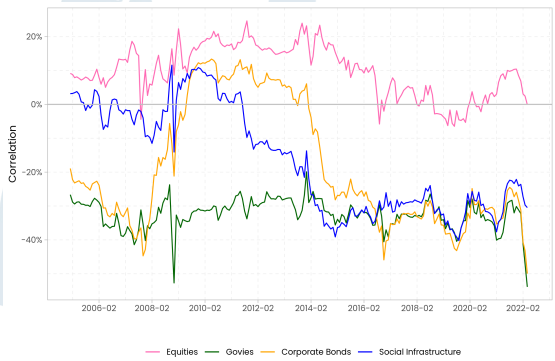
Table 12: Drawdown statistics, price returns, Equities, Bonds, Transport, Social Infrastructure and Network Utilities 2000-2022

	Equities	Govies	Corporate Bonds	Transport	Social Infra	Net. Utilities
Average Drawdown	0.1287	0.0506	0.0683	0.0415	0.0437	0.0557
Worst Drawdown	0.4976	0.1573	0.2884	0.1964	0.2762	0.2538
Average Length	18.3571	13.9474	19.2857	6.4571	7.2333	9.6154
Average Recovery	11.8571	6.8421	9.5000	3.0286	3.0333	4.6538
Cond. Drawdown*	0.3896	0.1003	0.1609	0.0952	0.1104	0.1203

* 5% conditional drawdown at risk

Figure 14: Social Infrastructure price returns

(a) Correlations with interest rate shocks

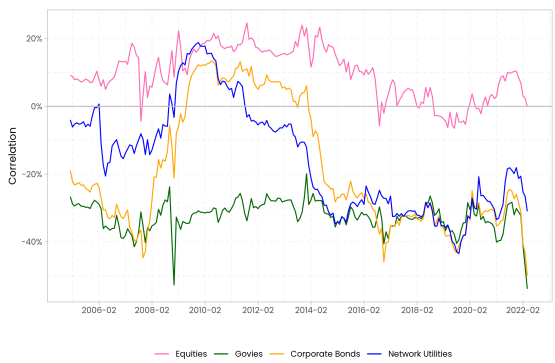


(b) Correlations with equity risk premium shocks

Source: Datastream, infraMetrics®, 60-month rolling correlations

Figure 15: Network Utilities price returns

(a) Correlations with interest rate shocks

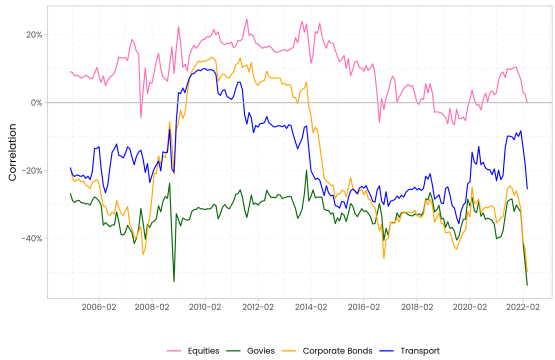


(b) Correlations with equity risk premium shocks

Source: Datastream, infraMetrics®, 60-month rolling correlations

Figure 16: Transportation price returns

(a) Correlation with interest rate shocks



(b) Correlations with equity risk premium shocks

Source: Datastream, infraMetrics®, 60-month rolling correlations

As with the global market, there are two periods of interest with regard to the equity co-skewness and co-kurtosis: the period between 2008 (the subprime crisis) and 2014, during which all segments exhibit significant negative co-skewness with stocks and the period after March 2020 (the Covid-19 pandemic) during which co-skewness and co-kurtosis with stocks and corporate bonds are negative and positive, repsectively, indicating a greater tendency to experience extreme negative returns.

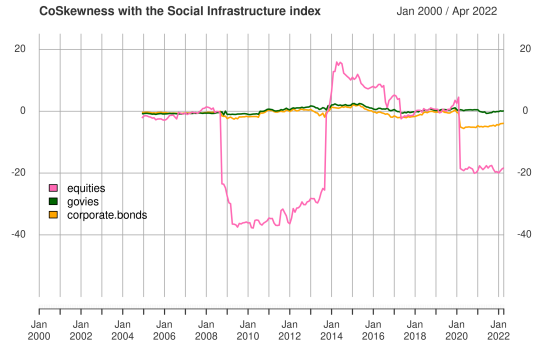
Sectoral differences are also visible in the order of magnitude of co-movements: the Covid-19 lockdowns impacted Transport Companies more than other types of infrastructure due to travel restrictions, airport closures, logistical bottle-necks, etc. As a result, their price returns were more likely to be both more extreme and negative than the general stock market and, to some extent, the corporate bond market.

Conversely, Social Infrastructure was less impacted by the Covid-19 shock than it was by the subprime crisis, which triggered an increased in risk premia across all financial assets.

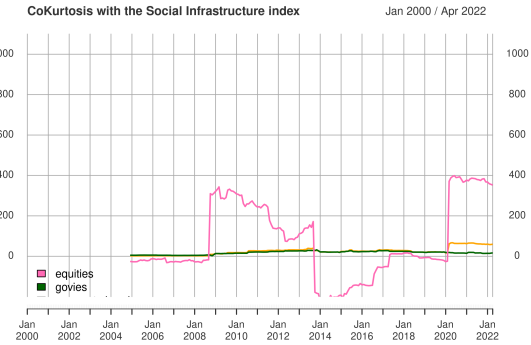
Thus, different infrastructure segments have had different reactions to economic and financial shocks depending on their economic profile (revenue growth), distribution policies (dividend growth) and exposure to interest rate and risk premium risk. When infrastructure companies are more correlated to the business cycle, as is the case with Trasport Companies, they can also recover from shocks faster.

Figure 17: Co-moment of Social Infrastructure and capital market returns

(a) Co-skewness



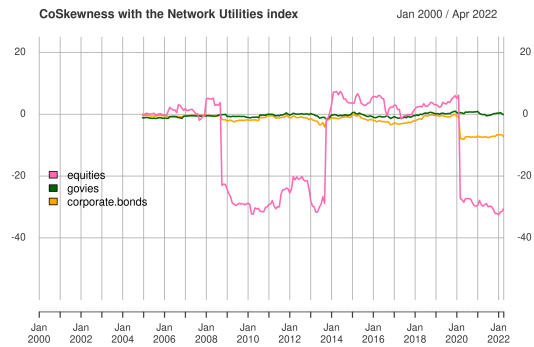
(b) Co-kurtosis



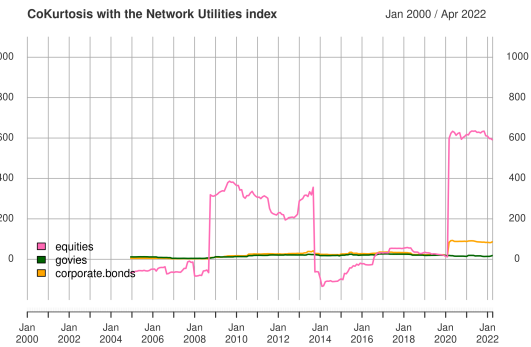
Source: Datastream, infraMetrics®, 60-month rolling co-moments

Figure 18: Co-moment of Network Utilities and capital market returns

(a) Co-skewness



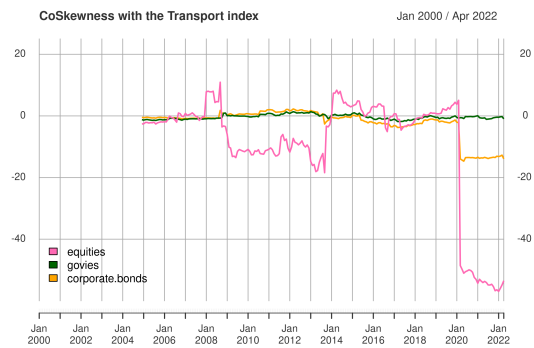
(b) Co-kurtosis



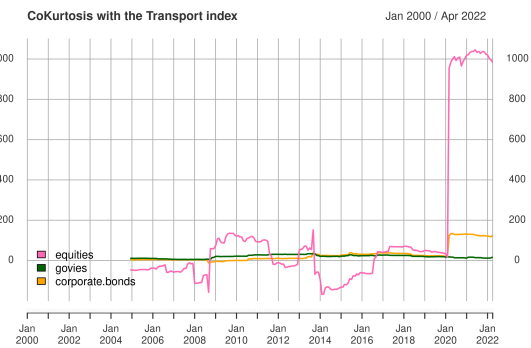
Source: Datastream, infraMetrics®, 60-month rolling co-moments

Figure 19: Co-moment of Transportation and capital market returns

(a) Co-skewness



(b) Co-kurtosis



Source: Datastream, infraMetrics®, 60-month rolling co-moments

8. Conclusions

In conclusion, we report the following stylised facts:

1. **Unlisted infrastructure is not immune to market shocks**: infrastructure asset prices exhibit a similar behaviour in times of stress as other asset classes: economic, financial and policy shocks lead to lower asset values. They also lead to higher cash returns since infrastructure companies, taken on aggregate, tend to pay very stable dividends. In other words, we do not find zero or negative correlations between infrastructure and capital markets; instead we find positive, significant and time-varying return correlations with both stocks and bonds.

2. **There is good evidence of downside protection**: the level of drawdown and extreme losses observed in unlixted infrastructure equity during periods of market stress is lower than in listed equities, greater than in government bonds and often close tothat of corporate bonds.

3. **Risk premium correlations increase in bad times**: unlisted infrastructure equity returns become more positively correlated with equities in times of crisis and infrastructure shares some tail risk with equities, especially during the subprime crisis and the Covid pandemic. These were periods when extreme co-movements of returns were more likely to occur in both asset classes. This coincidence of losses in bad times is due to simultaneous increases in the equity risk premium of each asset class.

4. **Interest rate risk matters**: Infrastructure equity investments share characteristics with bonds, especially via their exposure to interest rate risk. Return correlations with bonds are always positive and robust and shocks to the level of interest rates impacts infrastructure as much as bonds of comparable duration and convexity. Infrastructure equity also shares some tail risk with corporates bonds but not of the same order of magnitude as with listed equity, i.e., corporate credit spreads do not covary a lot with the infrastructure equity risk premium. Infrastructure equity does not exhibit common tail risk with government bonds.

5. **Different types of infrastructure weather shocks differently**: comparing a highly contracted and project-based segment of the unlisted infrastructure sector (SocialInfrastructure) with more regulated (Utilities) or merchant sectors (Transports) reveals that discount rate shocks can have a greater impact on contracted infrastructure. The more stable and typically long cash flow profile of contracted assets makes them more vulnerable to rate shocks because they cannot grow future cash flows commensurably. Meanwhile, riskier business models, like those of regulated utilities or toll roads, can partly offset higher rates with higher future cash flows, either because they benefit from an inflation pass-through or pricing power.

6. **Not all shocks have the same impact**: Different types of shocks impact infrastructure investments differently: recessions coincide with lower returns through the cash flow channel but also because of a general increase in the risk premium. Financial crises also lead to a higher risk premium and typically a higher level of stress. Still a public debt crisis like the Eurozone crisis does not have this effect, which is consistent with the

absence of joint tail risk as shown by the very low higher return co-moments between infrastructure and government bonds.

7. **Inflation risk is really interest rate risk**: Inflation risk is difficult to observe directly given the absence of inflation shocks in the past 20 years of data, with the exception of the first months of 2022. However, to the extent that higher inflation leads to immediate and positive shifts in the yield curve, it is largely related to interest rate risk, which is well-documented over the past 20 years, especially the sensitivity or return in a very low rate environment. As interest rates increase, the long duration of infrastructure can imply large losses. However, different levels of convexity – sensitivity to large changes in rates – are found in infrastructure business models and imply different levels of exposure. The more infrastructure businesses can partly offset higher discount rates thanks to higher cash flows, either from revenue indexation or growth.

8. **Infrastructure is good for the portfolio**: Infrastructure remains a potent diversifier of the portfolio even in times of stress. While correlations with capital markets do increase in bad times, they remain limited and the level of drawdown is much lower in infrastructure, especially on a total return basis. Still, the more extreme the risk and the deeper the impact on the economy, the more infrastructure investments tend to correlate with capital markets. This is consistent with the essential role played by infrastructure in an economy.

It should be noted that these results assume a well-diversified exposure to unlisted infrastructure assets and provide a comparison of risk and performance for many assets. The main infrastructure index used in this study is the infra300® which includes 300 constituents. In practice, many investors may find themselves less diversified because unlisted infrastructure investments are large and illiquid, and it take times to build a significant portfolio. As a result, many investors in unlisted infrastructure equity may be more at risk than these results suggest.

These findings have risk management and prudential implications. They show that in times of market stress, while infrastructure does experience drawdowns and is exposed to a market risk premium and to a significant rate risk, it can protect the portfolio on the downside as long as investors are exposed to a well-diversified basket of infrastructure assets in which most asset-specific risk has been diversified.

This informs the evolution of the treatment of infrastructure assets under the EU Solvency framework or other pudential regulations. The resilience of infrastructure investments also explains, in part, why infrastructure has become increasingly attractive to investors, along with its ability to generate high income returns over the past two decades. These result also give some insights into what climate risks might look like for infrastructure investors. Transition risk are mostly policy driven and would impact many assets at the same time, effectively resetting future cash flows and the level of discount rates reflecting the risk of future cash flows.

A. Appendix

A.1 The infra300® Index

The infra300® index is an equally weighted index designed to match the TICCS® allocations of the global unlisted infrastructure equity investment universe. It is designed to trackthe structure of global infrastructure market by business model, industrial activity and corporare structure.

It covers 20 countries, 27 sectors and represents c.USD250bn of market value. The infra300® can be accessed via Bloomberg® or at indices.edhecinfra.com.

A.2 Glossary

- The nth **moment** about the mean of a random variable X is $\mu_n := E[(XE[X])^n]$, where E is the expectation operator.
- **Kurtosis** is the fourth standardized moment of a distribution, defined as

$$E\left[\left(\frac{X-\mu}{\sigma}\right)^4\right] = \frac{\mu_4}{\sigma^4}$$

  where μ_4 is the fourth central moment and σ is the standard deviation. Kurtosis is one descriptor of the shape of a probability distribution. Unlike the first two moments, Kurtosis has no unit.
- **Excess kurtosis** is defined as Pearson's kurtosis minus 3, and provides a simple comparison to the normal distribution. Distributions with a positive excess kurtosis are said to be leptokurtic. An example of a **leptokurtic** distribution is the Laplace distribution, which has tails that asymptotically approach zero more slowly than a Gaussian, and therefore produces more outliers than the normal distribution. Distributions with negative excess kurtosis are said to be **platykurtic**, meaning that it produces fewer and/or less extreme outliers than the normal distribution.
- **Skewness** is the third standardized moment of a distribution

$$E\left[\left(\frac{X-\mu}{\sigma}\right)^3\right] = \frac{\mu_3}{\sigma^3}$$

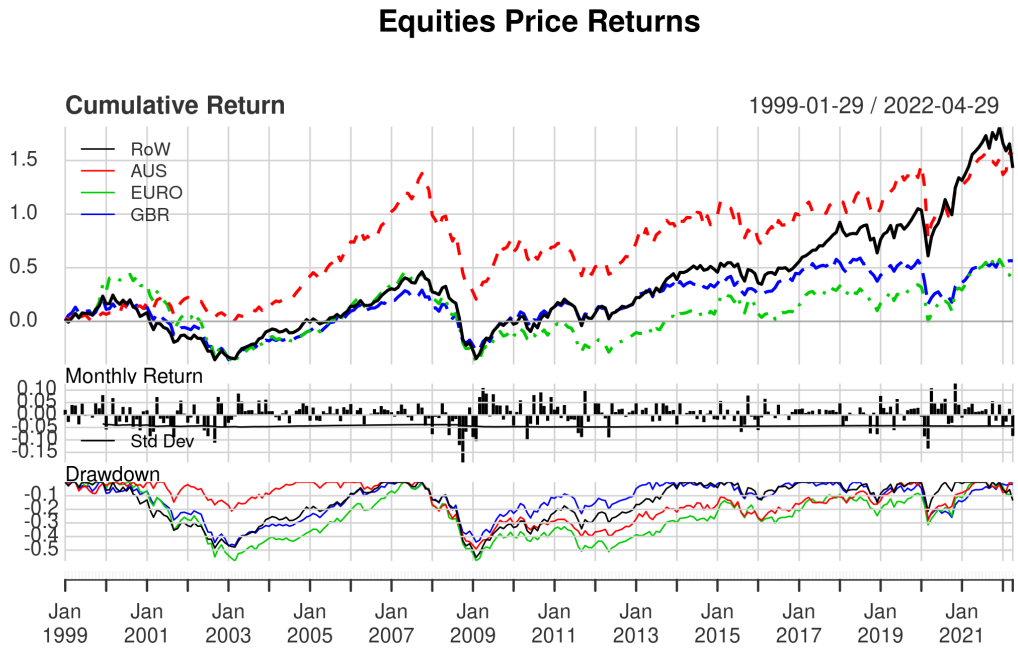
  where μ_3 is the third central moment and σ is the standard deviation. Skewness is also one descriptor of the shape of a probability distribution. High negative skewness in the distribution of returns indicates that large losses are possible. Like Kurtosis, skewness has no units: it is a pure number, like a z-score
- Co-kurtosis is the fourth standardized cross central moment i.e., a measure of how much two random variables change together. If two random variables X and Y exhibit high cokurtosis they will tend to exhibit extreme positive and negative deviations at the same time.

$$K(X,X,Y,Y) = \frac{E[(X-E[X])^3(Y-E[Y])]}{\sigma_X^3\sigma_Y^2}$$

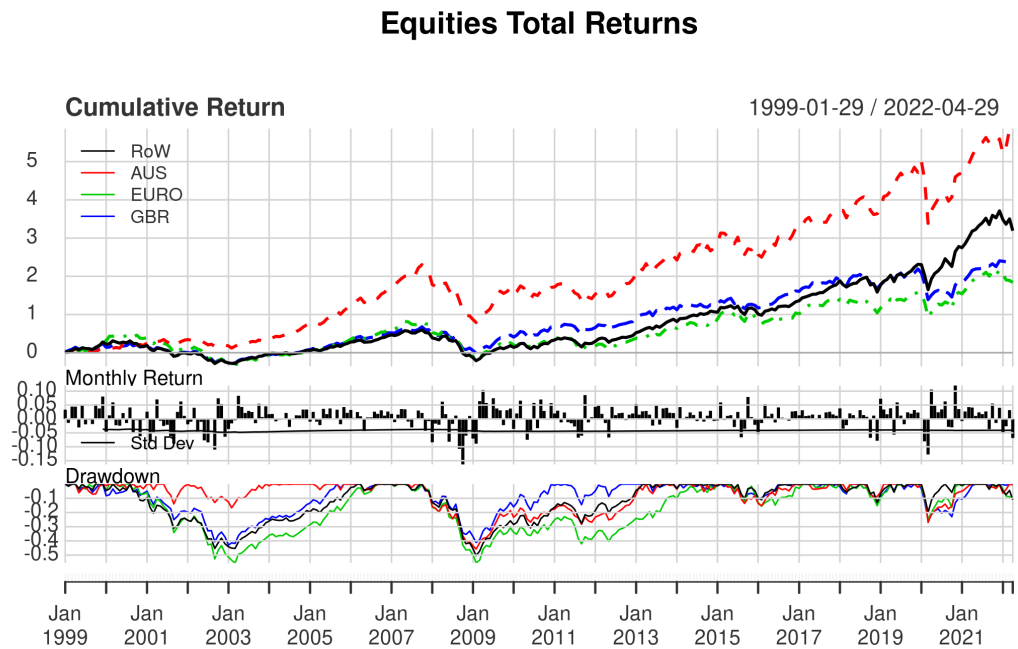
- Co-skewness is the third standardized cross central moment, related to skewness as covariance is related to variance. If random variables exhibit positive coskewness they will tend to undergo extreme deviations at the same time,

Figure 20: Market indices used to build the reference equity index

(a) Price Returns



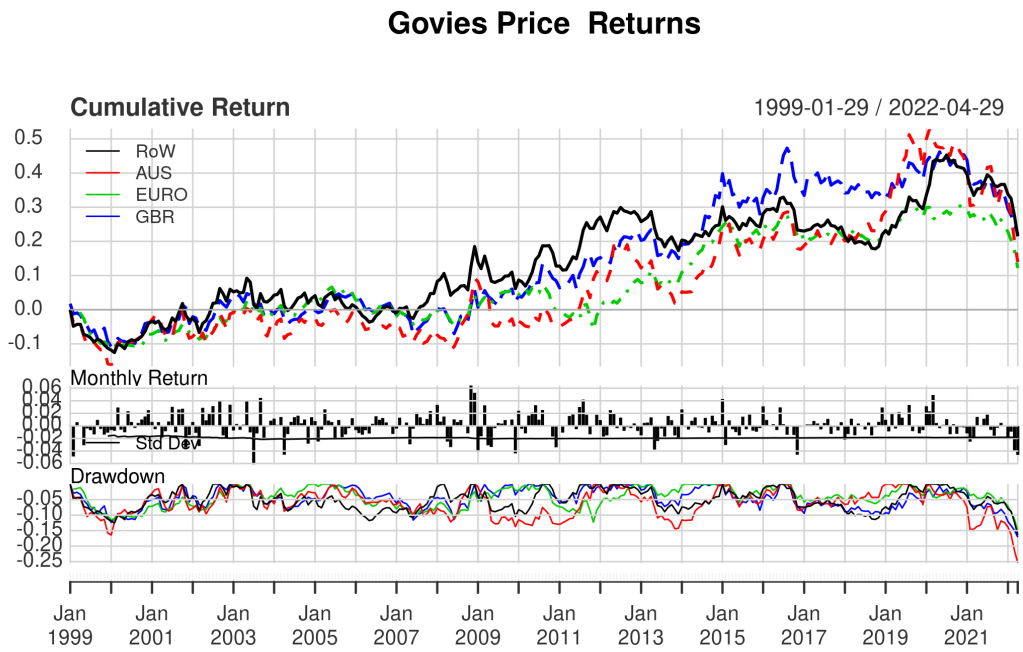
(b) Total Returns



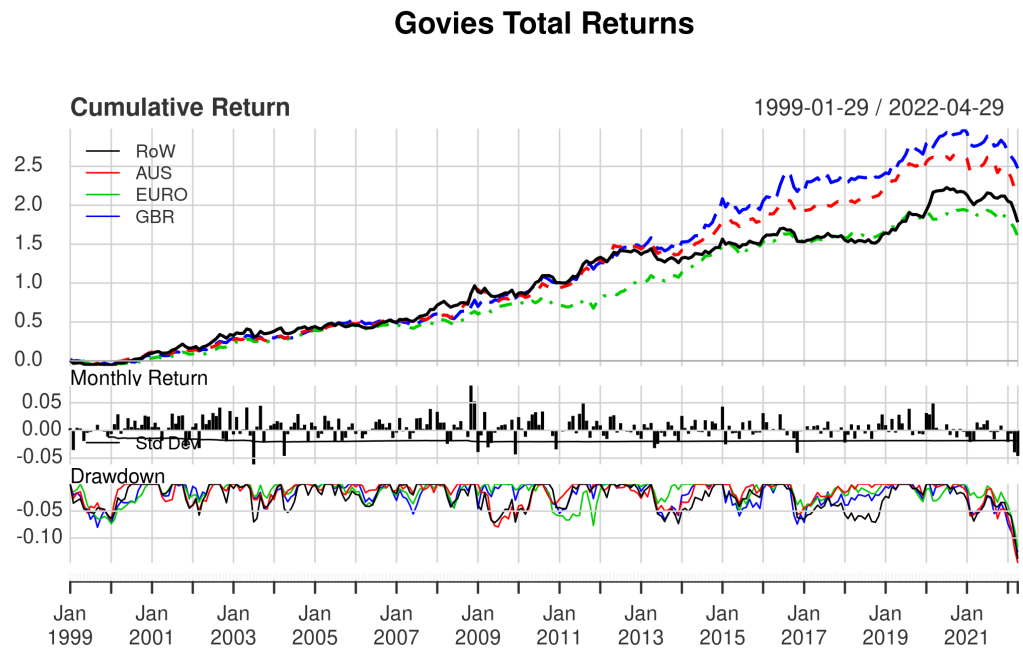
Source: Datastream

Figure 21: Market indices used to build the reference government bond index

(a) Price Returns



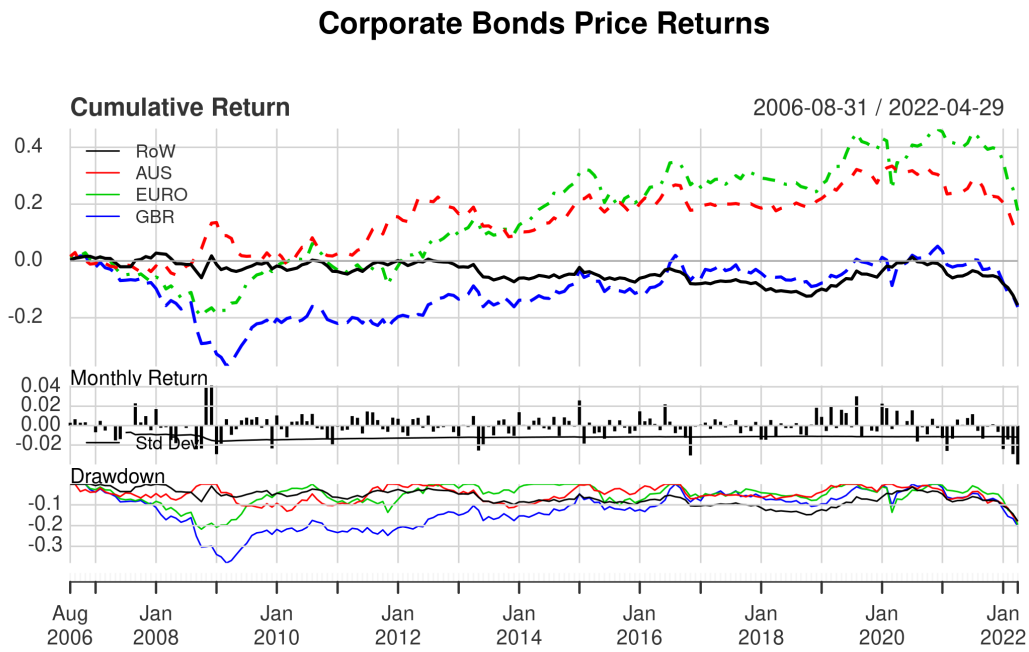
(b) Total Returns



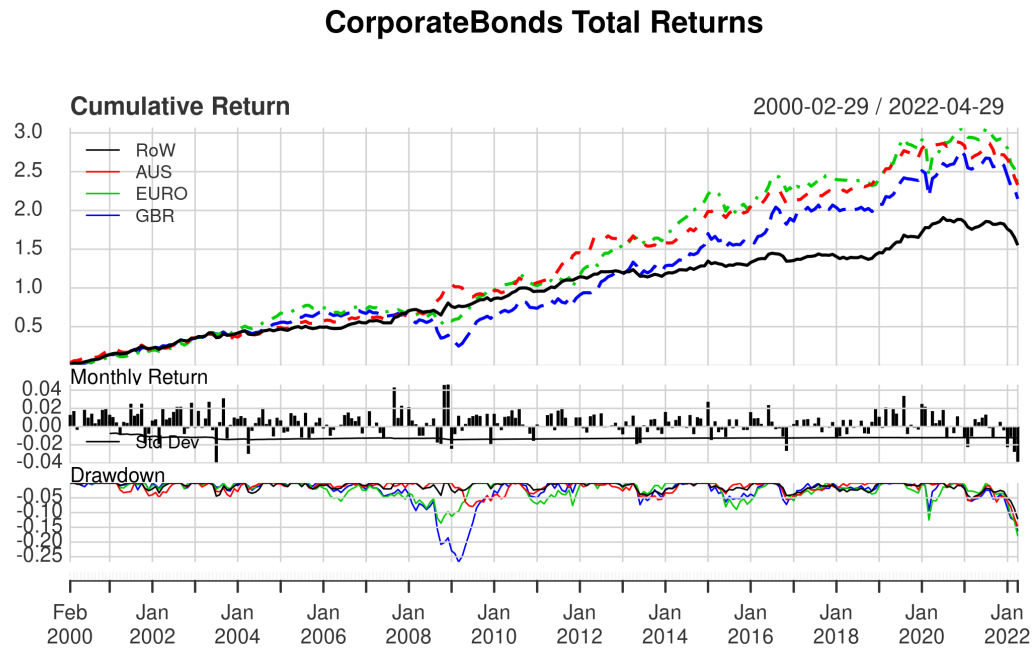
Source: Datastream

Figure 22: Market indices used to build the reference corporate bond index

(a) Price Returns

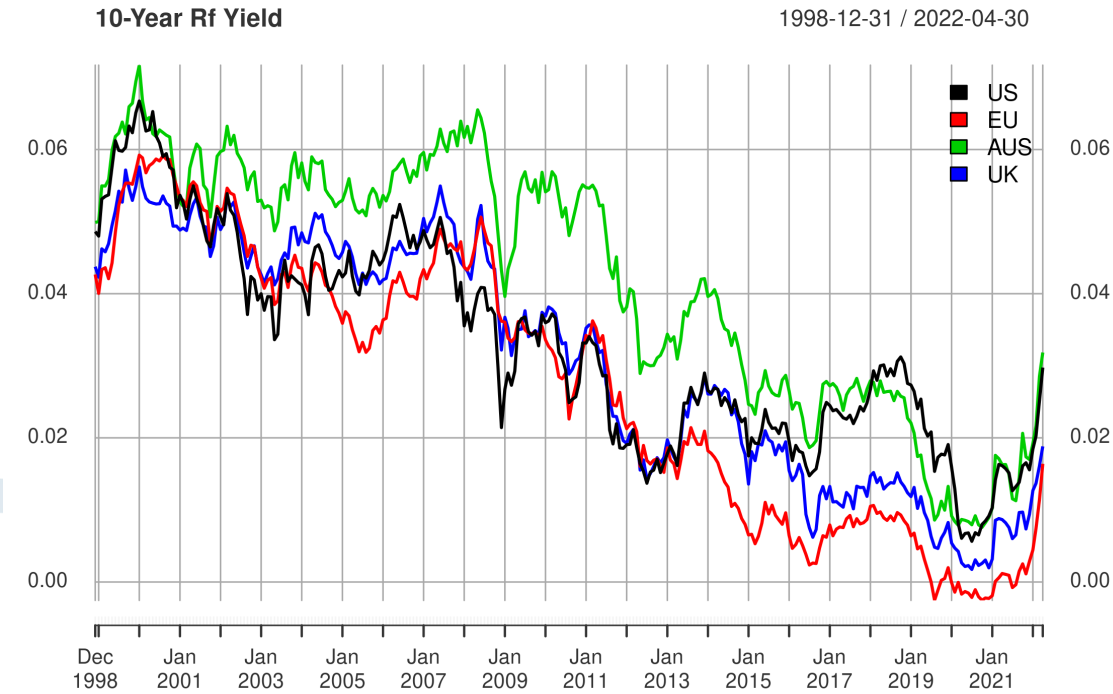


(b) Total Returns



Source: Datastream

Figure 23: 10-Year Bond Govermnent Yield



Source: Datastream

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Recent Publications (2020-2022)

EDHECinfra Methodologies & Standards

- The Infrastructure Company Classification Standard (TICCS) - Updated April 2022
- Credit Risk Methodology - April 2020
- Infrastructure Index Methodology Standard - Updated March 2020
- Global Infrastructure Investment Data Standard - Updated March 2020
- Unlisted Infrastructure Valuation Methodology - A Modern Approach to Measuring Fair Value in Illiquid Infrastructure Investments - Updated March 2020

Selected EDHEC Publications

- Blanc-Brude, F., A. Gupta., J.Lee, F. Nugier & T. Whittaker, "The cost of international sanctions to investors in Russia's airports" (March 2022)
- Amenc, N., F. Blanc-Brude, R. Tan, & T. Whittaker, "The cost of capital of brown gas" (February 2022)
- Blanc-Brude, F. & A. Gupta. "Robust Benchmarks for investors in private infrastructure funds" (November 2021)
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- Blanc-Brude, F., A. Gupta, "The Fair Value of Investments in Unlisted Infrastructure equity" (April 2021)
- N. Manocha, N. & F. Blanc-Brude "Towards a Scientific Approach to ESG for Infrastructure Investors" (March 2021)
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- Blanc-Brude, F., L. Lum, R. Tan & T. Whittaker, "The choice of performance test benchmark of Superannuation funds' investments in infrastructure" (December 2020)
- Amenc, N. & F. Blanc-Brude. "The Cost of Capital of Motorway Concessions in France - A Modern Approach to Toll Regulation" (September 2020)
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