PGIM
MULTI-ASSET SOLUTIONS

DIRECT INFRASTRUCTURE EQUITY

Performance, Return Attribution & Inflation Resilience

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Institutional investors are allocating more capital and resources to unlisted infrastructure investments for their purported stable and high income returns, relatively low correlation with other asset classes, and suitability for hedging long-duration liabilities. These characteristics, combined with investor attention to their nation's welfare, evolving regulatory requirements, and ongoing trends in the energy transition, have amplified the appeal of such investments.

Our previous infrastructure research focused on identifying the performance and cash flow characteristics of infrastructure investments (equity and debt) and examining their sensitivity to public equity and fixed income markets.[1] With an emphasis on liquidity risk in portfolio construction, we introduced a methodology to estimate direct infrastructure equity income returns, by sector and age, along with a new measure of infrastructure equity asset idiosyncratic risk. In addition, we provided a framework to help CIOs optimally allocate to infrastructure given their appetite for performance and liquidity risk.

We have since acquired a new infrastructure equity dataset from EDHEC*infra* that offers detailed asset-level financials (*e.g.,* profitability measures and valuation ratios), actual cash flows, and valuation data. Using this new dataset, we extend our study in infrastructure performance, valuation and return attribution.[2] We define the various components of infrastructure asset returns, distinguishing between price and income returns. We further examine how underlying drivers, *e.g.*, sales growth, valuation multiple expansion/contraction, drive infrastructure price returns, and then compare how these drivers affect public markets. We also evaluate how infrastructure assets respond to macroeconomic factors (*e.g.*, inflation) and correlate with broader public market returns. Finally, we discuss the pros and cons of an asset pricing methodology used for calculating infrastructure index returns.

1 Shen, J. and F. Blanc-Brude. (2022). *Building Portfolios with Infrastructure: Performance, Cash Flows & Portfolio Allocation*. PGIM and EDHEC*infra.*

2 We also use this dataset to re-examine the model parameters in to estimate infrastructure income returns. See our companion paper: Shen, J., *Income Returns of Infrastructure: Model Specification & Estimation*, forthcoming 2025, PGIM Multi-Asset Solutions.

CIO Takeaways

1. **High infrastructure equity income returns (and low price returns) – relative to public equity markets – have confounded investors. We review and clarify what "income return" means for an infrastructure equity asset.**
2. **Using an asset-level dataset, we break down infrastructure returns into income and price components, and find that infrastructure equity assets have, indeed, provided higher income returns (around 4-5%/y, net of costs) compared to public equity.**
3. **Infrastructure investments do carry significant asset-selection (*i.e.*, idiosyncratic) risk which might be effectively diversified with 10 or more equity assets.**
4. **Measuring price returns is challenging due to limited data. Bayesian techniques can help estimate periodic valuations and returns, but need careful interpretation.**
5. **Infrastructure has historically outperformed stocks and bonds during inflationary periods, supporting its role as a potential inflation hedge.**

Asset-level Infrastructure Equity Data

A lack of granular, asset-level data has limited investors' ability to evaluate the performance of infrastructure investments and their underlying return drivers. We use a newly-acquired asset-level infrastructure equity "dataset" comprising approximately 900 historical (including 600 "live") unlisted infrastructure assets from EDHEC*infra*'s infraMetrics database as of April 2024. For each asset, the dataset provides annual indicative and financial metrics. Figure 1 summarizes the dataset coverage by sector, region, business risk, corporate structure, and age group. To ensure meaningful time-series coverage and to avoid distortions from short-lived observations, we exclude data prior to 2007 and remove observations from 2023 onwards. We further exclude assets older than 25y.

Figure 1: Infrastructure Equity Asset-level Dataset Coverage[3]

Sector	Number of Assets
Transport	244
Renewable Power	188
Power Generation x-Renewables	150
Network Utilities	115
Social Infrastructure	84
Energy and Water Resources	64
Environmental Services	36
Data Infrastructure	34
Sum	**915**

Age Group	Number of Assets
Greenfield	691
Operating	592
Brownfield	345
Mature	690

Business Risk	Number of Assets
Contracted	530
Merchant	220
Regulated	165
Sum	**915**

Region	Number of Assets
Europe	650
Oceania	135
Asia	72
South America	31
North America	27
Sum	**915**

Corporate Structure	Number of Assets
Corporate	260
Projects	655
Sum	**915**

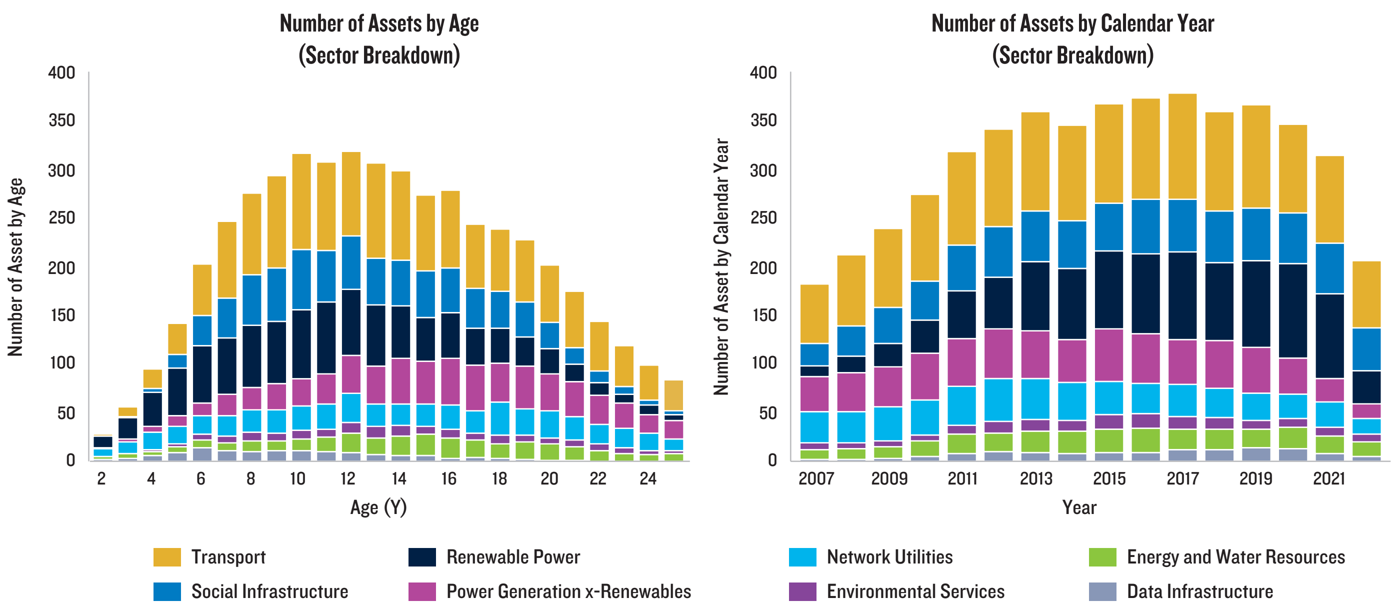
Source: PGIM Multi-Asset Solutions, EDHEC. For illustrative purposes only.

Figure 2 shows the number of assets in the dataset, by age and calendar year. The composition of infrastructure sectors has evolved significantly over the past two decades. Early samples were heavily weighted toward traditional infrastructure assets (*e.g.*, transport, regulated utilities) but have since broadened to include more renewable energy, data infrastructure (such as data centers), and other

3 We define asset age group by years in operation in line with EDHEC*infra*: Greenfield (<5y), Operating (6-10y), Brownfield (11-20y) and Mature (>20y). Assets are also categorized by business risk into: **Contracted:** Fixed payments under long-term agreements, typically with the public sector; **Merchant:** Revenues depend on market demand and user payments. **Regulated:** Returns set by regulators in monopoly-like sectors.

emerging sectors. This shift not only reflects changes in investor preferences and policy incentives – such as the global push for energy resilience – but also the inclusion of new technologies that were nascent 20y ago. As sectors have matured, some older, once-prevalent segments have diminished in relative importance (*e.g.*, transport) while emerging infrastructure sectors (*e.g.*, renewable power) have grown, changing the risk-return profile of the overall market.

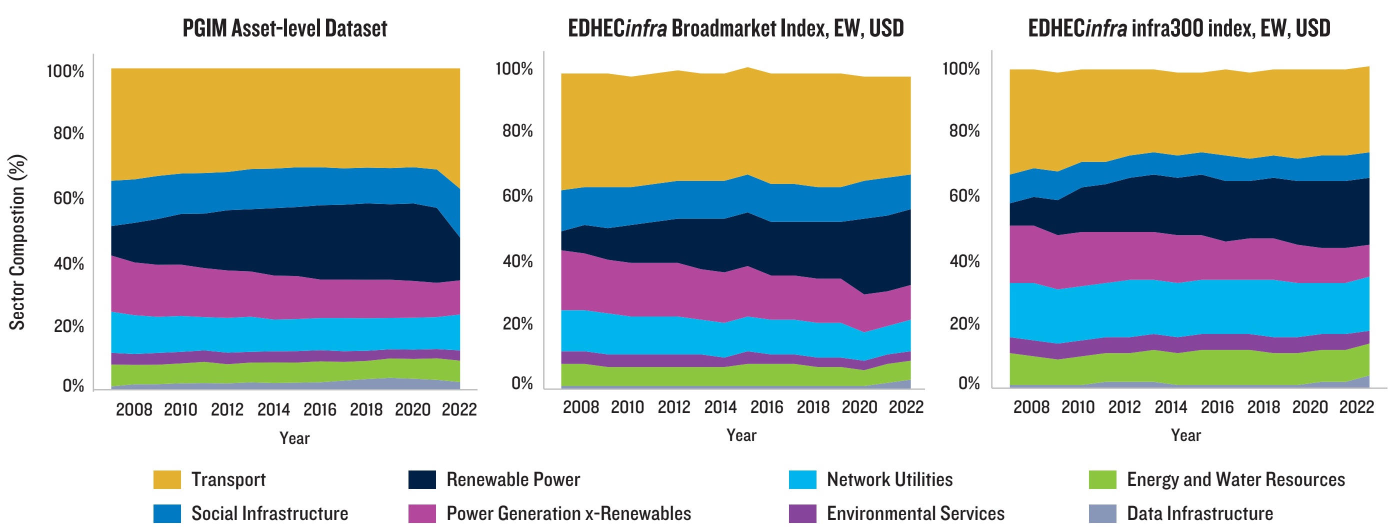
Figure 2: Number of Infrastructure Assets, by Calendar Year and Age (Asset-Level Dataset)



Source: PGIM Multi-Asset Solutions, EDHEC. For illustrative purposes only.

Figure 3 compares the sector composition in the asset-level dataset with that of EDHEC*infra*'s **Broadmarket**[4] and **infra300**[5] indices. While some variations appear in certain sectors, such as Transport, the overall composition remains broadly consistent across the three series. This indicates that the asset-level dataset reflects similar market-wide trends identified by the aggregated indices. For details on the dataset, please refer to the Appendix.

Figure 3: Sector Composition Comparison: Asset-Level Dataset *vs.* EDHEC*infra* Indices



Source: PGIM Multi-Asset Solutions, EDHEC. For illustrative purposes only.

4 The Broadmarket Equity Index represents the monthly total return of all 600 "live" unlisted infrastructure companies.

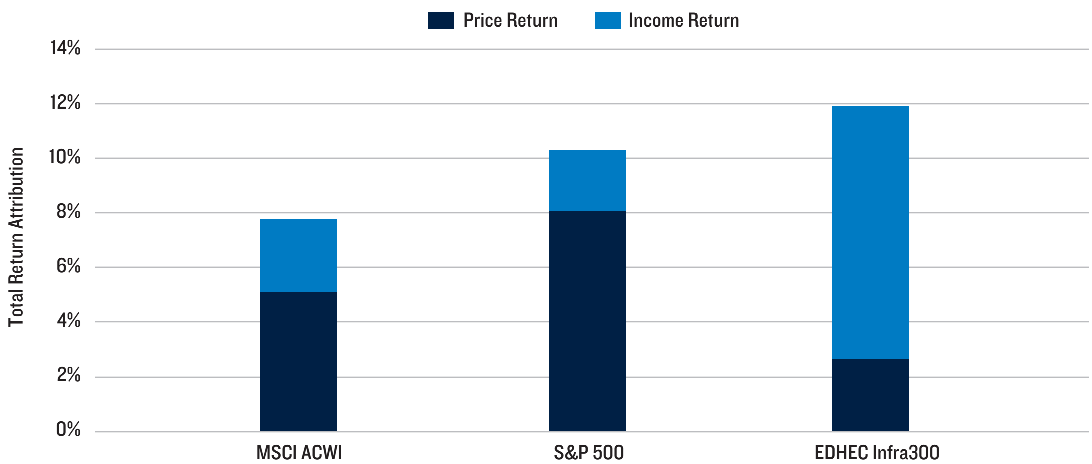
5 The infra300® Equity Index is a comprehensive global index that represents the monthly total return of 300 unlisted infrastructure companies. This index is different from the EDHEC*infra* asset-level infrastructure equity dataset we use, which comprises approximately 900 historical and 600 "live" unlisted infrastructure assets from EDHEC*infra*'s infraMetrics database as of April 2024.

Infrastructure Equity Asset Total Return Attribution

Total return attribution helps investors observe where their returns are coming from, and understand the specific characteristics associated with each total return component. Income return often represents a steadier, more predictable stream, while price return is generally more volatile. Total return attribution can help investors make better informed decisions to align their portfolios with investment objectives.

Leveraging the dataset, we aim to enhance investors' understanding of key return drivers by attributing reported total returns to their price and income return components and comparing these results across the MSCI ACWI, S&P 500, and the EDHEC infra300 indices. Notably, infrastructure equity has a significantly higher proportion of income return which greatly exceeds that of traditional public equity indices. These very high income returns (and very low price returns) – relative to public markets – have confounded investors and motivates our research.[6] We also explore how infrastructure's high reported income returns might impact portfolio construction, especially if managing liquidity risk is a key goal.

Figure 4: Total Return Attribution Comparison: Public Equity and Infrastructure (EDHEC infra300)



Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. For illustrative purposes only.

Total return attribution for infrastructure equity assets can be tricky, especially for investors more familiar with public markets. Attribution requires a clear definition of the return components which, as we explain below, can be confusing since many of these assets are backed by project finance structures. In addition, data providers differ in their return component definitions, making it challenging for investors to compare across both data providers and asset classes.

In project finance, equity investors typically contribute capital in two forms: common equity and shareholder loans (SHLs) (Figure 5). SHLs resemble preferred equity as it is subordinate to all debt holders. SHLs serve two main purposes: providing a tax shield and allowing shareholders to extract cash even when the project is unprofitable. SHLs are typically issued conjoined ("stapled") with common equity, forming part of the total capital an equity investor commits to a project or company. In other words, *common equity return* is only a part of the *total return to an equity investor*. SHLs can represent a significant portion of an equity investor's paid-in capital.

Figure 5: Balance Sheet for an Infrastructure Asset

Asset	Liability & Equity	
Cash	Account Payable	
Current Asset	Short Term Senior Loan	
Non-current Asset	Long Term Senior Loan	
	Shareholder Loan (SHL)	Total Shareholder Equity
	Common Equity	

Source: PGIM. For illustrative purposes only.

6 EDHEC*infra* refers to what is commonly known as income return as "cash return" (or "cash yield") which measures the cash received in relation to the value of the asset at the beginning of a period.

The Role of Shareholder Loans

Shareholder loans in infrastructure financing offer tax advantages and enhance cash flow flexibility.[7] Unlike traditional debt instruments, where interest payments are contractually required at set intervals, interest payments on SHLs are discretionary. So, while interest may accrue it is not mandated to be paid at regular intervals. The terms vary, but generally, if the borrower were to face a cash constraint, they could defer SHL interest payments. Since shareholder loans are considered debt for accounting purposes, the (optional) interest payments on these loans reduce the project's earnings before tax (EBT) which, in turn, reduce the corporate tax liability.

Another benefit of SHLs is the ability to circumvent restrictions on equity dividend distributions in jurisdictions where companies with negative retained earnings are prohibited from paying dividends. Infrastructure projects, such as those in renewable energy, often experience negative retained earnings in their initial years due to high depreciation and amortization. This may prevent the distribution of income to shareholders despite positive cash flows. Shareholder loans address this issue by allowing shareholders to receive interest payments, and **repayments** of SHL principal, outside the constraints of dividend regulations. This mechanism allows cash to be returned to investors, and these earlier cash distributions can enhance a project's internal rate of return (IRR).

$$Total\ Equity\ Value = Value\ of\ Shareholder\ Loan + Value\ of\ Common\ Equity$$

$$Income\ to\ Equity\ Investor = Shareholder\ Loan\ Interest + Dividends$$

$$Total\ Return_t = Income\ Return_t + Price\ Return_t$$

$$Price\ Return_t = \frac{(Ending\ xDiv.\ Equity\ Value_t)}{Beginning\ Total\ Equity\ Value_t} - 1$$

$$Income\ Return_t = \frac{SHL\ Interest\ Paid_t + Dividends\ Paid_t}{Beginning\ Total\ Equity\ Value_t}$$

An Illustration of a Total Return Attribution Example

The total equity value of an infrastructure project is the sum of common equity and SHL values. The income to equity investors consists of both SHL interest earned and equity dividends received. Total equity return can then be attributed to two components:

- **Price return** reflects changes in total market value (*i.e.*, common equity plus SHLs); and
- **Income return** includes periodic SHL interest payments and common equity dividends.

Figure 6 illustrates the calculation of the total return components for equity investors.

Figure 6: A Hypothetical Equity Total Return Attribution Example

Cash Flows (At the End of the Year)						Equity Value				Total Return Attribution		
Asset	Date	SHL Drawdown	SHL Repayment	SHL Interest	Div. Paid	Beginning Equity Value	Ending Cum-Div. Equity Value	Ending x-Div. Equity Value	Ending Equity Value (After CF Adjustment)	Price Return	Income Return	Total Return
		a	b	c	d	e	f	g = f - c - d	h = g + a - b	i = g/e-1	j = (c + d)/e	k = i + j
ABC	12/31/17	10	5	1	2	100	103	100	105	0.00%	3.00%	3.00%
ABC	12/31/18	0	3	1	3	105	115	111	108	5.70%	3.80%	9.50%
				Equity Investor's Income								

Source: PGIM Multi-Asset Solutions. For illustrative purposes only.

7 See L. Duldinger, (2023) *What's the Purpose of a Shareholder Loan?* Renewables Valuation Institute. https://courses.renewablesvaluationinstitute.com/pages/academy/whats-the-purpose-of-a-shareholder-loan.

Total Equity Value:

- Beginning Equity Value (**e**): The starting equity value at the beginning of the year, including the outstanding value of SHLs;
- Ending cum-Div. Equity Value (**f**): The adjusted equity value before subtracting SHL interest payments (**c**) and common equity dividends (**d**);
- Ending x-Div. Equity Value (**g**): The adjusted equity value after subtracting SHL interest payments (**c**) and common equity dividends (**d**);
- Ending Equity Value (after CF Adjustment) (**h**): The final equity value after all cash flow adjustments, which include SHL drawdowns and SHL repayments.

Total Equity Cash Flows:

- SHL Drawdowns (**a**): New SHL fund injections that increase the outstanding shareholder loan value. These drawdowns affect the project's cash flow but not its operating income. SHL drawdowns are added to the Ending Equity Value (after CF Adjustment) (**h**);
- SHL Repayments (**b**): Principal repayments to equity investors, which reduce the outstanding SHL value. SHL repayments are subtracted from the Ending Equity Value (After CF Adjustment) (**h**);
- SHL Interest (**c**): Periodic interest income paid to equity investors on the outstanding shareholder loan; and
- Common Dividends Paid (**d**): Distributions of the project's earnings to equity investors.

We define equity investor's income return as the sum of SHL interest (**c**) and common equity dividends (**d**). Because SHL Drawdowns (**a**) and Repayments (**b**) represent either contributions to, or return of, capital, they do not affect income return – but rather affect the ending equity value. In contrast, SHL Interest (**c**) and Dividends Paid (**d**) are considered *returns on capital* and are therefore included in income return.

- Price Return (**i**): The capital appreciation relative to the Beginning Equity Value;
- Income Return (**j**): The ratio of SHL interest plus common equity dividends to the Beginning Equity Value; and
- Total Return (**k**): The sum of Price Return (**i**) and Income Return (**j**).

EDHEC*infra*'s Infrastructure Equity Asset Total Return Component Definition

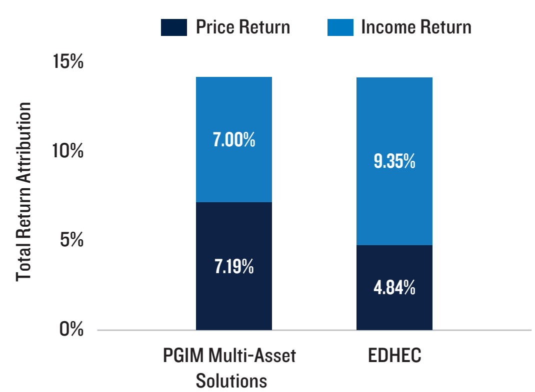
$$Total\ Return_t = Cash\ Return_t + Price\ Return_t$$

$$Price\ Return_t = \frac{(Ending\ xDiv.\ Equity\ Value_t\ - \mathbf{SHL\ Repayment_t})}{Beginning\ Total\ Equity\ Value_t} - 1$$

$$Cash\ Return_t = \frac{\mathbf{SHL\ Repayment_t} + \ SHL\ Interest_t + Dividends\ Paid_t}{Beginning\ Total\ Equity\ Value_t}$$

Due to the different approach between PGIM and EDHEC*infra* in total return decomposition, there is a difference in return attribution – sometimes a substantial difference – even though the total returns are the same.[8] Figure 7 compares these two approaches. From 2007 to 2022, our income return component is 7.0%/y, with price return contributing 7.2%/y. In contrast, EDHEC*infra* produces a much higher income return component of 9.4%/y and a lower price return of 4.8%/y.

Figure 7: Total Return Attribution Comparison
(2007 to 2022, Gross of Mgmt. Cost)



Source: PGIM Multi-Asset Solutions, EDHEC*infra*. For illustrative purposes only.

8 Note that this study is based on the asset-level dataset instead of the EDHEC infra300 index.

Income Return

These differences in income return likely stem from the treatment of SHL repayments. EDHEC*infra* treats a SHL repayment as a "cash return." However, this treatment is not appropriate for total return attribution. Since a SHL repayment is not a return *on* capital, like SHL interest or common equity dividends, but rather a return *of* capital, we do not include SHL repayments in the income return calculation. While cash return may be relevant for liquidity risk analysis, for return attribution, income return is the relevant measure.

Price Return

For an illiquid asset class, calculating a price return can be challenging as there are typically few observed primary and secondary unlisted infrastructure transactions. Based on available transaction values, EDHEC*infra* calculates a periodic equity price for *all* unlisted infrastructure equity assets in its indices.[9] These estimated periodic valuations are the basis for computing price returns.
To estimate valuations, EDHEC*infra* employs a discounted cash flow (DCF) approach to produce a "fair market value" of an infrastructure equity asset. This fair market value is a function of three components: the asset's projected cash flows, the term structure of interest rates, and an estimated equity risk premia for the asset derived from a calibrated factor model.

The valuation formula is:

$$P_{i,t} = \sum_{t}^{t+T} \frac{Cash\ Flow_{i,\,t}}{(1 + rf_t + \widehat{\gamma_{i,t}})^t} \qquad (1)$$

where:

$\boldsymbol{P_{i,t}}$ is the present equity value of asset $\boldsymbol{i}$ at time $\boldsymbol{t}$;

$\boldsymbol{Cash\ Flow_{i,t,}}$ cash flows to equity investors in asset $\boldsymbol{i}$ at time $\boldsymbol{t}$ (EDHEC*infra* forecasts cash flows by modeling a asset's free cash flow to equity and a retention rate using a statistical model that takes into account future debt service and the asset's lifecycle);

$\boldsymbol{rf_t}$ is the risk-free rate (observed term structure of interest rates); and

$\boldsymbol{\gamma_{i,t}}$ is the estimated equity risk premia.

The asset's equity risk premia is estimated using:

$$\widehat{\gamma_{i,t}} = \sum_{k} \widehat{\lambda_{k,t}} \beta_{k,i,t} \qquad (2)$$

where:

$\boldsymbol{\beta_{k,i,t}}$ represents asset $\boldsymbol{i}$'s exposure to risk factor $\boldsymbol{k}$ (an asset's observable attributes, including size, financial leverage, profitability, interest rate term spread, value and growth) at time $\boldsymbol{t}$, and

$\boldsymbol{\lambda_{k,t}}$ is the estimated price of each risk factor $\boldsymbol{k}$ at time $\boldsymbol{t}$.

To estimate $\boldsymbol{\gamma_{i,t}}$ EDHEC*infra* uses Bayesian techniques based on observed transaction prices in the unlisted infrastructure market. This process involves:

- **Prediction Stage:** Using previous estimates to forecast current risk premia, and
- **Updating Stage:** Adjusting estimates based on the difference between predicted and realized equity risk premia.

However, this dynamic updating faces several challenges:

- **Data Scarcity:** Limited transaction data can hinder reliable risk premia estimation;
- **Initial Prior Assumptions:** Improper initial assumptions can affect estimation accuracy; and
- **Slow Adaptation:** Difficulty adapting to structural change may delay risk premia updates, lagging current market conditions.

9 Blanc-Brude, F. (2018) "*Unlisted Infrastructure Asset-Pricing Methodology: A Modern Approach to Measuring Fair Value in Illiquid Infrastructure Investments.*" EDHEC*infra.*

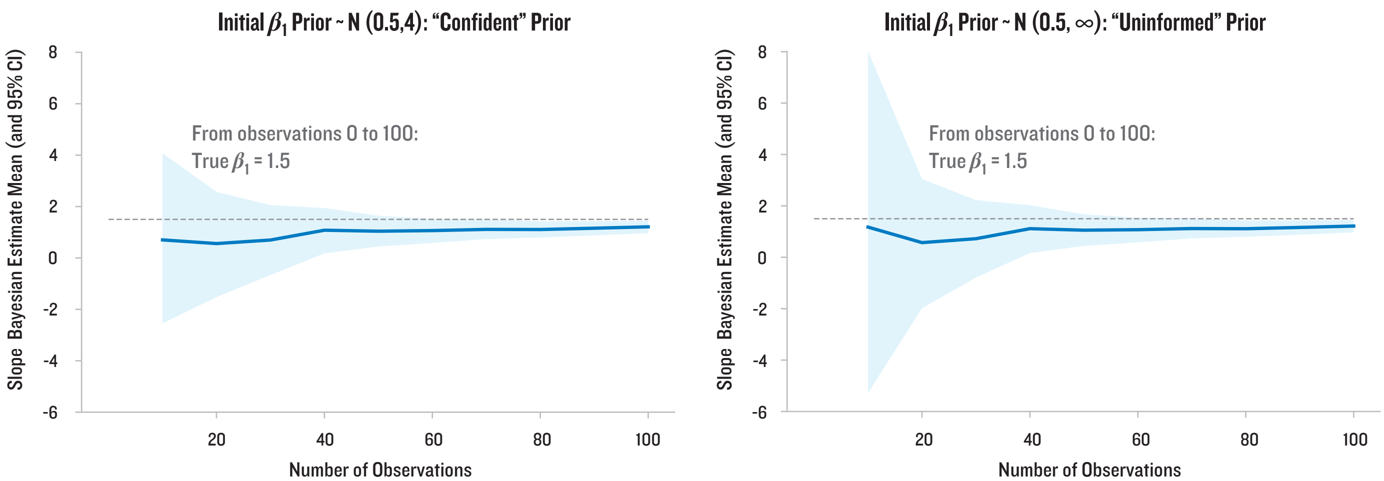
These concerns suggest that while the pricing methodology is robust in theory, practical limitations of data availability and estimation methods may impact the accuracy of asset valuations. To demonstrate the workings of the Bayesian approach, let's assume we wish to estimate the relationship between infrastructure returns and public equity returns. In other words, we want to estimate the sensitivity of $\boldsymbol{\beta_1}$ (not the $\boldsymbol{\beta_{k,i,t}}$ in formula 2) of private asset returns $\boldsymbol{R_{private}}$ to public equity returns $\boldsymbol{R_{pub\ equity}}$:

$$R_{private} = \beta_0 + \beta_1 R_{pub\ equity} + \epsilon \quad (3)$$

Unfortunately, there are limited observations of infrastructure returns. Before observing any data, we assume a "prior distribution" for $\boldsymbol{\beta_1}$ that follows a N(0.5, 4). Updates occur incrementally as new infrastructure returns data (based on the limited number of actual infrastructure transactions over time) are collected. Initially, the estimate of $\boldsymbol{\beta_1}$ is highly uncertain with a wide confidence interval. The confidence interval narrows over time as more data are incorporated. This is the desired Bayesian updating process.

The choice of the Bayesian prior significantly affects the estimation of $\boldsymbol{\beta_1}$, particularly during the *early stages of data collection*. To illustrate (Figure 8) we consider an alternative "uninformed" prior distribution, N(0.5, ∞). This prior, of course, results in a wider range of posterior estimates compared to the more informative prior, N(0.5, 4), used in the earlier example. This increased uncertainty leads to greater initial variability in the $\boldsymbol{\beta_1}$ estimate, making inference less reliable. However, as more data become available, the influence of the prior diminishes, and the confidence intervals under *both* prior distribution assumptions converge. By around the 50th observation, the estimates stabilize, suggesting that even with an uninformative prior, Bayesian updating allows for meaningful inference once sufficient data have been accumulated. For asset classes with limited transactions data (*e.g.,* observations), the issue for investors is "Has there been sufficient updating for the time series to be reliable for conducting portfolio construction?"

Figure 8: The Impact of a Very Uncertain Prior

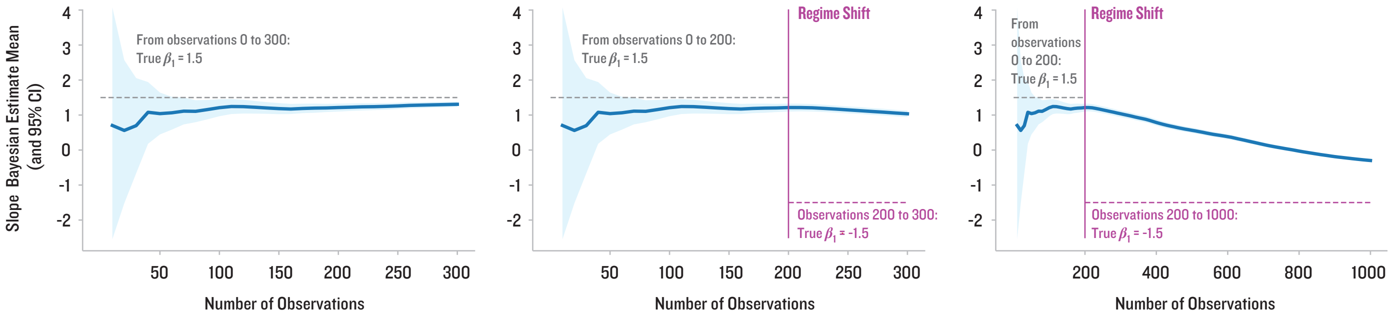


Note: To represent an uninformed prior, we choose 1,000,000 as the variance for Beta prior. We try even larger variances, but the chart and takeaway remain intact. Source: PGIM Multi-Asset Solutions, EDHEC*infra*. For illustrative purposes only.

Another potential limitation of the Bayesian approach is its difficulty to adapt to structural changes, such as a regime shift in the relationship between private and public asset returns. Given the growth, institutionalization, and exposure to changing governmental policy, it may be that infrastructure is an asset class relatively more exposed to regime shifts.

Figure 9 illustrates the potential problem. Suppose the *true* $\boldsymbol{\beta_1}$ shifts (say, due to a shift in investor appetite for infrastructure arising from a regulatory change) from 1.5 to -1.5 after 200 observations. Nevertheless, Bayesian estimates for $\boldsymbol{\beta_1}$ remain biased toward the prior regime, struggling to adjust due to the narrow variance of the prior. Note that *at least 200 observations* (a long time in the case of infrastructure transactions) are needed for the 90% confidence interval for $\boldsymbol{\beta_1}$ to shrink below 0.2. While Bayesian updating is a powerful tool for updating parameter estimates, its effectiveness is limited in the presence of regime shifts, as the prior (distribution) constrains the speed of adaptation. While the passage of time naturally lengthens the published time series of infrastructure returns, investors should view these longer times series with caution. As shown in Figure 8, even recent returns can be heavily influenced by the initial Bayesian prior.

Figure 9: An Illustrative Example for Bayesian Updating



Source: PGIM Multi-Asset Solutions. For illustrative purposes only.

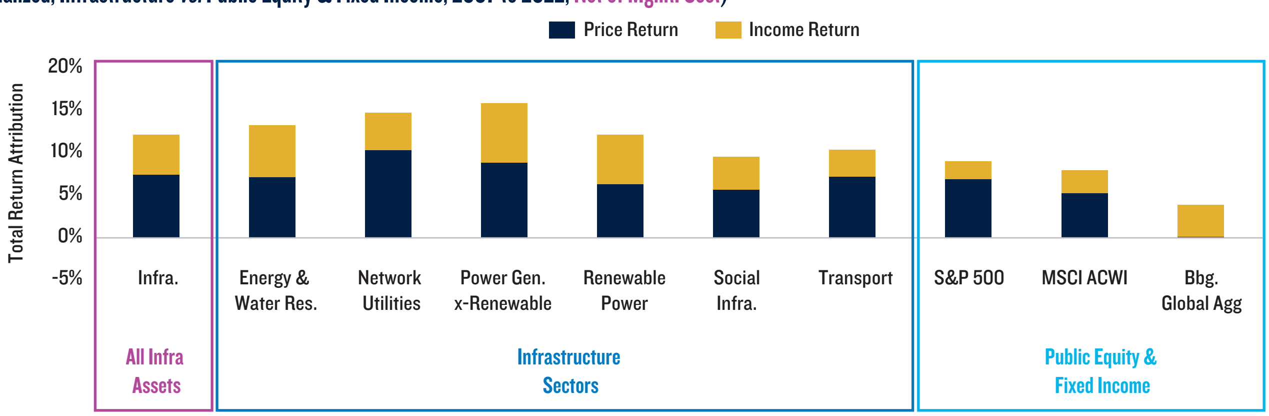
Comparing Infrastructure Equity to Public Equity and Fixed Income

Before comparing *direct* infrastructure equity and public assets, one must account for the management costs inherent in direct infrastructure – costs such as labor, maintenance, and operational resources. Unlike public equity or private equity *funds*, where management fees are reflected in net returns, direct infrastructure returns are reported as gross returns without deducting these costs. To ensure an apples-to-apples comparison, we deduct 2.5%/y in management cost from annual infrastructure income returns. This cost estimate is based on the typical labor expense private asset managers incur during their investment processes.[10]

After accounting for management costs, infrastructure assets demonstrate an income return of approximately 4-5%/y (Figure 10). This is notably higher – although much less than some index providers report – than the income returns from public equity (and low risk bonds) which generally range between 2% and 4%. Power Generation x-Renewables, Energy & Water Resources, and Network Utilities stand out by delivering strong income returns compared to other sectors. This enhanced income potential indicates that infrastructure equity, on average, can provide attractive income over time, making it an option for investors seeking consistent income returns.

Figure 10: Infra Equity Asset Total Return Attribution (PGIM Approach) – Price Return & Income Return

(Annualized, Infrastructure *vs.* Public Equity & Fixed Income, 2007 to 2022, Net of Mgmt. Cost)



Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. For illustrative purposes only.

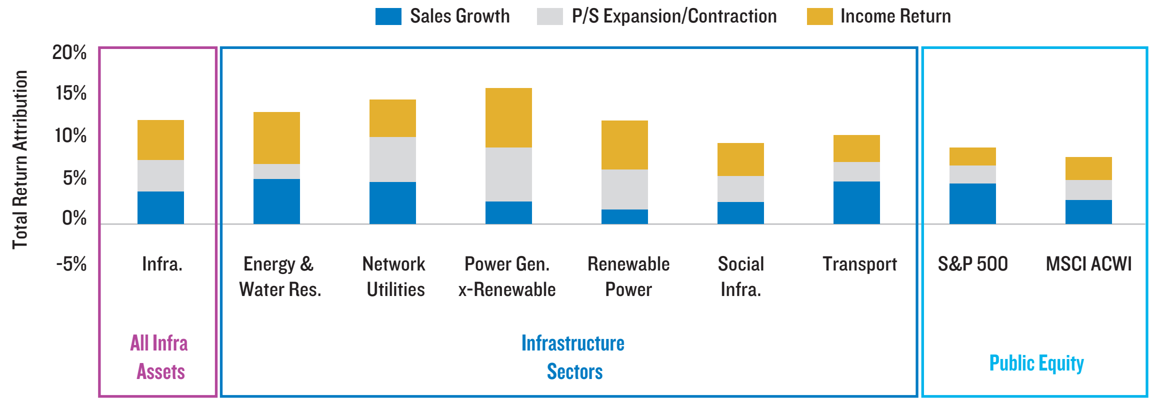
Figure 11 takes a closer look at the drivers of the infrastructure price return component: sales growth and changes in the Price/Sales ratio. For infrastructure, net income is often negative, especially in capital-intensive sectors such as renewable energy due to high non-cash expenses such as depreciation and amortization, making percentage changes less meaningful. For return attribution, we use sales growth and P/S (Price-to-Sales ratio) expansion/contraction instead of earnings growth and P/E expansion/contraction to avoid distortions caused by negative reported earnings.[11] This allows for a better understanding of how much of the price return comes from a company's improving fundamentals (*i.e.*, growing revenues) versus changes in market valuation (*i.e.*, P/S multiple expansion).

10 We use the average labor expense of two listed private asset managers (*i.e.,* KKR and Blackstone) incurred during their investment process over the past three years as a proxy for the management costs an institutional investor (*e.g.*, a sovereign wealth fund) would incur when directly investing in unlisted infrastructure investments.

11 P/S ratio compares a company/project's equity price to its revenue per share. It is especially useful for evaluating companies that aren't yet profitable with negative earnings.

On average, the price returns of sectors like Energy & Water Resources, Network Utilities and Transport were driven more by sales growth than by P/S multiple expansion. In contrast, Power Generation ex-Renewables, Renewable Power and Social Infrastructure benefited more from an upward re-rating of their valuations. For public equity indices, such as the S&P 500 and MSCI ACWI, most of the price return and total return came from sales growth.

Figure 11: Infra Equity Asset Total Return Attribution (PGIM Approach) – Sales Growth, P/S Expansion/Contraction & Income Return (Annualized, Infrastructure *vs.* Public Equity, 2007 to 2022, Net of Mgmt. Cost)



Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. For illustrative purposes only.

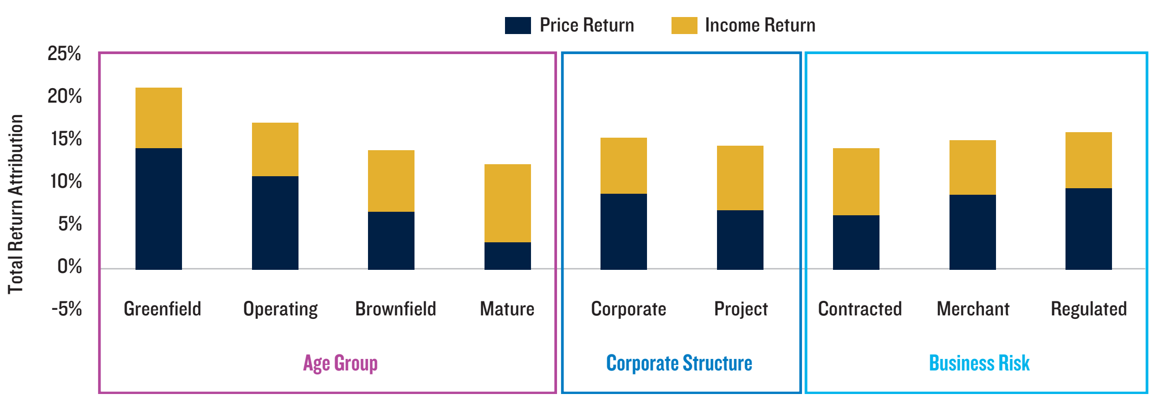
Total Return Attribution by Asset Age, Corporate Structure and Business Risk

We segment infrastructure assets by business risk, corporate structure, and age to provide a closer look into return attribution across different asset types. Infrastructure assets are categorized based on their corporate structures and their specific business risks. **Project** companies are established solely to build and operate specific infrastructure assets and are often structured as single-project entities, such as special purpose vehicles (SPVs). In contrast, **infrastructure corporations** manage multiple projects across different sectors, offering a more diversified risk exposure.

The interrelationship between business risk and corporate structure can be observed across different sectors. For example, assets in the **Renewable Power** and **Power Generation x-Renewables** sectors are typically **contracted** project assets which provide investors with stable income through fixed payouts secured by long-term contracts. On the other hand, nearly half of **Transport** sector assets are exposed to **merchant** risk where income streams are variable and depend on future, and potentially volatile financial results driven by factors such as pricing and demand.. In addition, most **Network Utilities** assets function as **regulated** natural monopolies under frameworks designed to ensure services are provided at reasonable cost. As a result, **projects** typically generate higher income returns than **corporates** (Figure 12). Notably, **contracted** assets, despite offering the lowest price returns, tend to provide the highest average income returns.

An infrastructure asset's **age** (*i.e.,* greenfield, operating, brownfield or mature) also plays a significant role in return attribution. As assets mature, their income returns generally increase as a percentage of their total returns, while price returns tend to decline (Figure 12).

Figure 12: Infra Equity Asset Total Return Attribution (PGIM Approach) – Price Return & Income Return (Annualized, Infrastructure Equity by Age, Corporate Structure and Business Risk, 2007 to 2022, Gross of Mgmt. Cost)

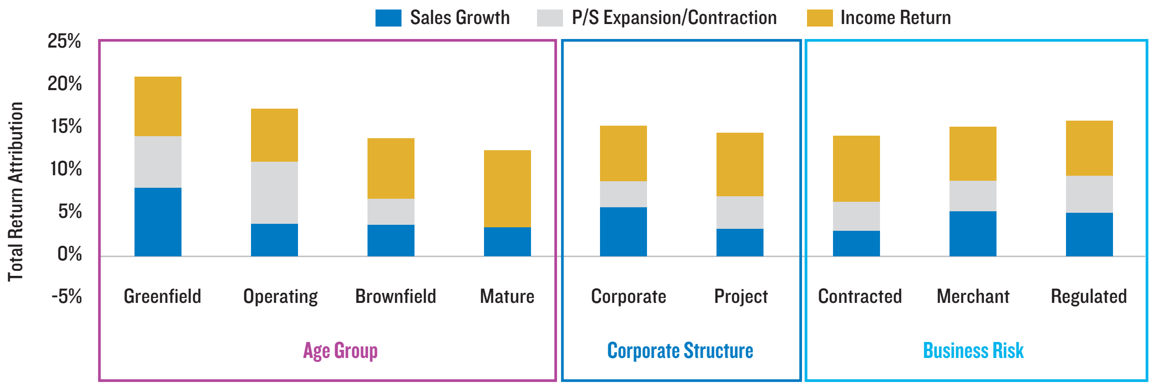


Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. For illustrative purposes only.

We extend our attribution analysis to infrastructure segments by business risk, corporate structure, and age (Figure 13). Corporates typically experienced higher sales growth compared to projects and merchant and regulated assets saw higher sales growth compared to contracted assets. Interestingly, both sales growth and multiple expansion have tended to decrease with age. This trend may be attributed to an asset's natural lifecycle: as an asset matures its sales growth may decelerate, and this deceleration may affect the asset's valuation and anticipated future cash flows.

Figure 13: Infra Equity Asset Total Return Attribution (PGIM Approach) – Sales Growth, P/S Expansion/Contraction & Income Return

(Annualized, Infrastructure Equity by Age, Corporate Structure and Business Risk, 2007 to 2022, Gross of Mgmt. Cost)



Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. For illustrative purposes only.

Unlisted Infrastructure Equity Investments in a Multi-Asset Portfolio

We examine key metrics for asset allocation involving unlisted infrastructure, including volatility and correlation with public equity and fixed income. These metrics provide insights into infrastructure's risk-return characteristics and may help investors assess its role in a multi-asset portfolio.

Income and Price Return Volatility

Infrastructure assets carry high idiosyncratic risk, which is often not fully captured when examining returns at the aggregate (*i.e.,* index or sector) level. While aggregate-level analysis provides insights into general income and price returns, it can overlook the substantial variation across assets, even within the same sector. Since infrastructure investments are large and infrequent, with relatively few assets in an investor's portfolio, this substantial cross-asset variability underscores the need for CIOs to account for the high degree of **selection risk** associated with infrastructure assets.

When investors access reported sector-level returns for infrastructure they are viewing a measure of returns averaged across a range of assets within the sector. Using these time series of returns generates an aggregate volatility measure, which drowns out individual asset volatility. However, investing directly in relatively few infrastructure assets is the norm for many institutional investors and these infrastructure portfolios will exhibit more unpredictable or "lumpy" behavior in terms of income and price returns compared to asset-class level behavior. In other words, unlike the case for public stock and bond investors, direct infrastructure investors will have more difficulty diversifying to reduce the (uncompensated) idiosyncratic component of their returns. Therefore, accurately measuring and managing volatility in this asset class requires incorporating this **idiosyncratic risk** – specific to individual assets – as well as the broader index-level **time series risk** that reflect market or sector-wide trends. *Combining these risk measures* provides a fuller understanding of the risks associated with infrastructure investments.

Figure 14 breaks down the total annual income and price return volatility, respectively, into time-series volatility and cross-sectional return volatility. While time-series income return volatility tends to be small, all sectors show much higher cross-sectional income return volatility which becomes the main driver behind asset-level total income return volatility. *This suggests that infrastructure equity investments could provide stable income if sufficiently diversified at the sector level.* In contrast, price return volatility is significantly higher than income return volatility, where both time series price return volatility and cross-sectional price return volatility are high.

Figure 14: Infrastructure Equity Asset's Income Return, by Sectors (2007-2022)

Sector	Count	Expected Annual Income Return	Times Series Annual Income Return Volatility	Cross-sectional Annual Income Return Volatility	Total Income Return Volatility
Power Generation x-Renewables	94	9.2%	2.4%	10.8%	11.2%
Environmental Services	22	9.1%	3.4%	9.3%	9.9%
Energy and Water Resources	41	8.4%	2.0%	7.6%	8.4%
Renewable Power	151	8.1%	2.0%	9.3%	9.2%
Network Utilities	72	6.7%	1.5%	5.9%	6.3%
Social Infrastructure	72	6.2%	0.9%	5.4%	5.8%
Transport	185	5.6%	1.1%	7.3%	7.7%
Data Infrastructure	23	3.9%	2.1%	4.7%	6.8%

TICCS Business Risk	Count	Expected Annual Income Return	Times Series Annual Income Return Volatility	Cross-sectional Annual Income Return Volatility	Total Income Return Volatility
Contracted	390	7.5%	0.4%	8.7%	8.8%
Merchant	162	6.1%	1.4%	8.3%	8.6%
Regulated	108	6.3%	1.2%	6.2%	6.6%

TICCS Corporate Structure	Count	Expected Annual Income Return	Times Series Annual Income Return Volatility	Cross-sectional Annual Income Return Volatility	Total Income Return Volatility
Corporate	168	6.3%	1.1%	6.9%	7.1%
Project	492	7.2%	0.5%	8.8%	8.8%

Age Group	Count	Expected Annual Income Return	Times Series Annual Income Return Volatility	Cross-sectional Annual Income Return Volatility	Total Income Return Volatility
Greenfield	105	6.8%	2.5%	5.1%	7.4%
Operating	391	6.0%	1.5%	7.2%	7.5%
Brownfield	543	6.9%	1.0%	8.4%	8.4%
Mature	250	8.8%	1.9%	8.9%	9.8%

Infrastructure Equity Asset's Price Return, by Sectors (2007-2022)

Sector	Count	Expected Annual Price Return	Times Series Annual Price Return Volatility	Cross-sectional Annual Price Return Volatility	Total Price Return Volatility
Data Infrastructure	23	11.2%	17.0%	24.3%	28.0%
Network Utilities	72	9.9%	9.1%	20.4%	22.6%
Power Generation x-Renewables	94	8.5%	6.8%	24.8%	25.5%
Transport	185	6.9%	7.3%	23.1%	25.3%
Environmental Services	22	6.9%	7.7%	20.9%	23.2%
Energy and Water Resources	41	6.9%	10.6%	18.3%	21.3%
Renewable Power	151	6.1%	6.2%	22.4%	24.5%
Social Infrastructure	72	5.5%	7.8%	15.1%	18.1%

TICCS Business Risk	Count	Expected Annual Price Return	Times Series Annual Price Return Volatility	Cross-sectional Annual Price Return Volatility	Total Price Return Volatility
Merchant	162	8.5%	7.4%	24.9%	26.9%
Regulated	108	9.2%	8.3%	20.9%	23.0%
Contracted	390	6.2%	6.3%	21.1%	22.8%

TICCS Corporate Structure	Count	Expected Annual Price Return	Times Series Annual Price Return Volatility	Cross-sectional Annual Price Return Volatility	Total Price Return Volatility
Corporate	168	8.6%	8.6%	22.0%	23.7%
Project	492	6.7%	5.8%	22.2%	23.8%

Age Group	Count	Expected Annual Price Return	Times Series Annual Price Return Volatility	Cross-sectional Annual Price Return Volatility	Total Price Return Volatility
Greenfield	105	13.7%	10.1%	18.5%	23.0%
Operating	391	10.5%	8.3%	22.6%	24.4%
Brownfield	543	6.6%	5.6%	21.3%	22.7%
Mature	250	3.1%	7.0%	21.8%	25.9%

Note: Time-series income return volatility ($\sigma_{\text{time-series}}$) is calculated as the volatility of average annual income returns over calendar years t: $\sigma(\text{Average Annual Income Return}_t)$; Cross-sectional income return volatility ($\sigma_{\text{cross-sectional}}$) is calculated as the average of cross-sectional volatility of individual asset i's annual income returns over calendar years: $E\left(\sigma\left(\text{Average Annual Income Return}_i\right)_t\right)$;
$\sigma_{\text{total}} = \sqrt{\text{Var}_{\widehat{\text{cross-sectional}}} + \text{Var}_{\text{time-series}}}$.

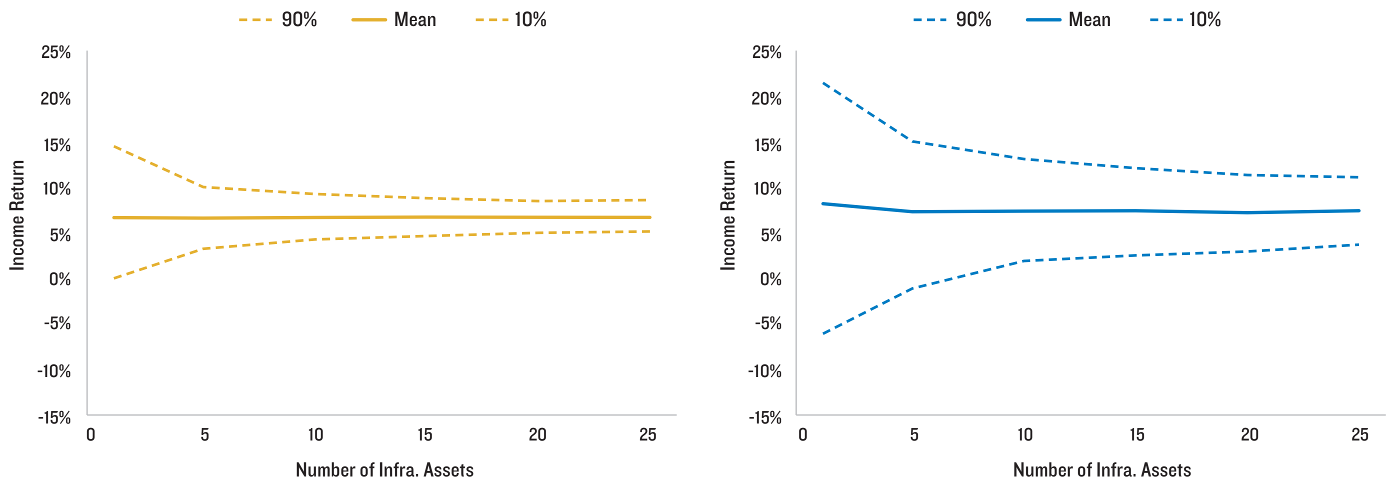
Source: PGIM Multi-Asset Solutions, EDHEC*infra*. For illustrative purposes only.

Diversifying the High Asset-Selection Risk

Due to the high cross-sectional idiosyncratic risk exhibited by infrastructure assets, it is crucial to diversify an infrastructure portfolio. But how many assets in a portfolio are needed to achieve effective diversification? Figure 15 demonstrates that as the number of infrastructure assets in a portfolio increases, the portfolio variability of both income and price returns narrows significantly. For income returns, the range between the 10th and 90th percentiles stabilizes around its mean when the portfolio contains 10 or more assets. Afterwards, the marginal risk reduction with one additional asset starts to become small. Similarly, the variability of price returns declines rapidly as the portfolio expands to 10-15 assets, after which further diversification yields only marginal reductions in variability. These findings also suggest that a portfolio of at least 10 assets is sufficient to provide, historically, a 90% confidence level of achieving at least 4.3% in income return and 1.9% in price return. By holding at least 10 assets, investors could have achieved relatively stable returns.[12] However, it is important to note that the results are gross of fees, and actual net-of-fee returns will be lower after accounting for management and transaction costs.

Figure 15: Diversification in Return Components of Infrastructure Portfolios

(Annualized, 2007 to 2022, Gross of Mgmt. Cost)



Source: PGIM Multi-Asset Solutions, EDHEC*infra*. Provided for illustrative purposes only. Please see Notice for important disclosures.

Correlation to Public Equity and Fixed Income

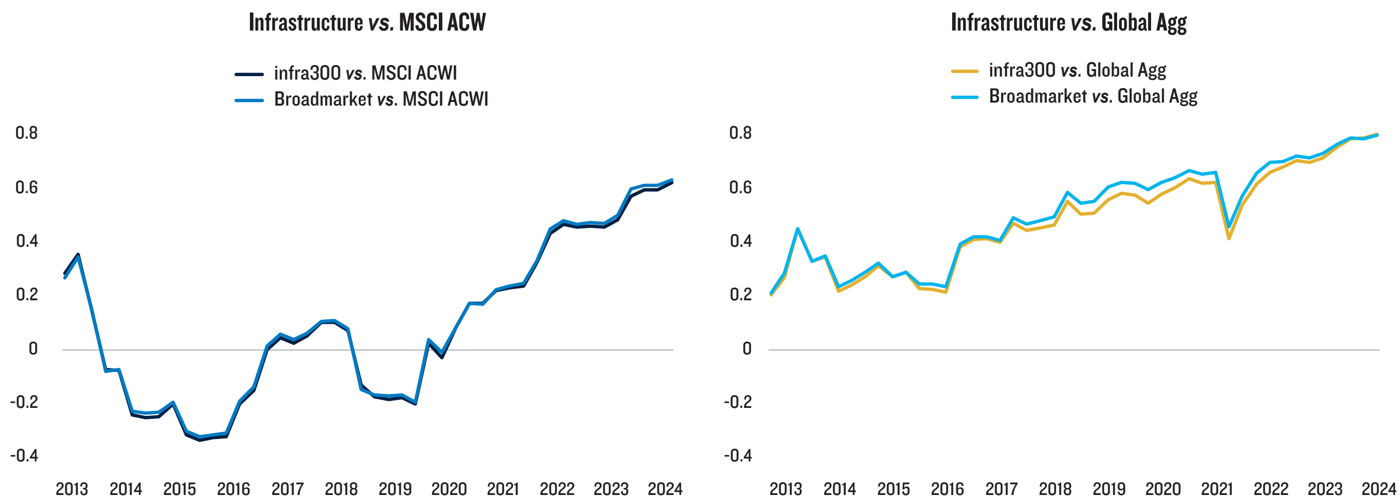
To demonstrate how infrastructure equity fits within a multi-asset portfolio, we analyze its correlation to public assets (*e.g.,* stocks and bonds), its impact on overall portfolio risk, and its potential diversification benefits. Over the past decade, infrastructure's rolling five-year correlation to global equities (MSCI ACWI) has risen from near zero or negative levels in the early 2010s to much higher levels – reaching around 0.6 or above by the mid-2020s – perhaps reflecting the maturity of the asset class in institutional portfolios. Similarly, infrastructure's correlation to global bonds, which also started at relatively low levels (around 0.2) in the early 2010s, has steadily climbed to the range of 0.7 to 0.8 by the early to mid-2020s. However, in 2022, a sharp rise in interest rates caused bond prices to decline more than infrastructure, leading to a brief drop in correlation to bonds.[13]

12 We found that simply increasing the number of assets, even within the same sector, can be nearly as effective as cross-sector diversification. See details in J. Shen and F. Blanc-Brude. (2022). "*Building Portfolios with Infrastructure: Performance, Cash Flows & Portfolio Allocation*." PGIM and EDHEC*infra.*

13 Data collection in the early years (prior to 2011) was relatively limited, with few transactions per year. By 2012–2013, annual transactions had reached a more consistent level of 50–70/y, with a cumulative total exceeding 300. So, the equity risk premium and prices estimated with Bayesian updating may not accurately reflect infrastructure equity returns during the pre-2013 period. As a result, the negative correlation between infrastructure equity and public assets in these years may not be reliable. To exercise extra caution, investors could start using data from 2012/2013 onward, with the first 5-year correlation available in 2018.

Figure 16: Infrastructure Rolling 5y Total Return Correlation with Public Equity and Fixed Income

(Q3 2008 to Q3 2024, Gross of Mgmt. Cost)



Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. For illustrative purposes only.

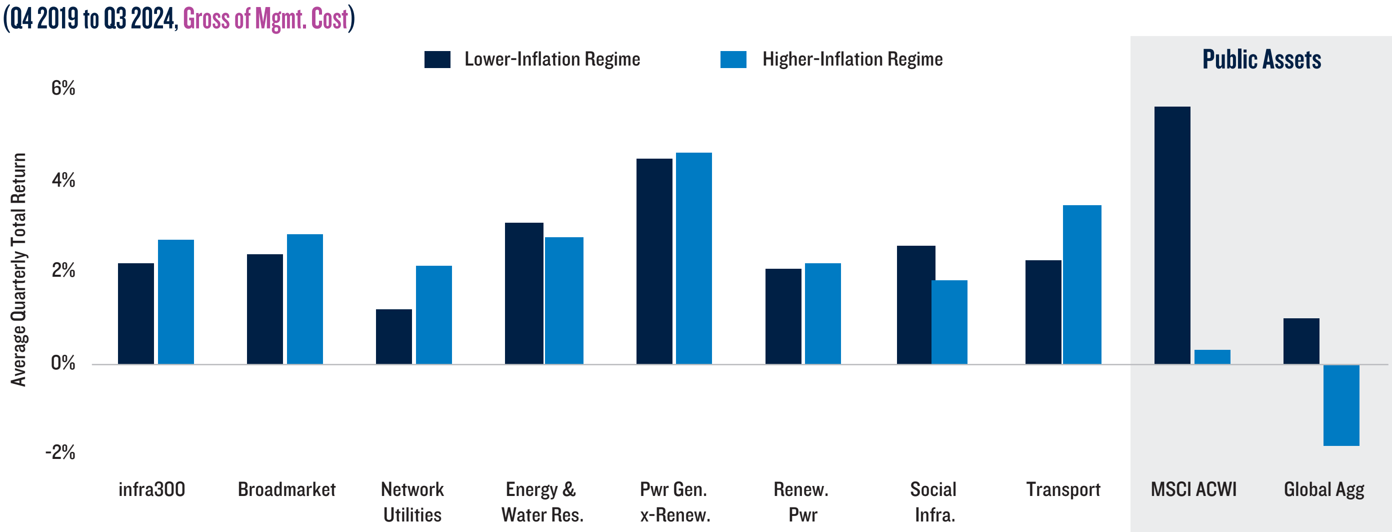
Infrastructure equity also exhibited a **beta of 0.5 to a 60/40 portfolio**, represented by MSCI ACWI and Bloomberg Global Aggregate. This suggests that while infrastructure assets are exposed to broader public market movements, they also provide meaningful diversification benefits in a multi-asset portfolio. Within infrastructure, beta estimates vary across sectors, ranging from 0.38 for Energy and Water Resources to 0.63 for Renewable Energy. These differences reflect variations in contractual structures, regulatory frameworks, and revenue stability across infrastructure sectors. Sector-level exposures allow for further customization based on an investor's risk and return objectives.

Inflation Resilience

Recent inflationary pressures have ignited interest in infrastructure as a potential inflation hedge. What is the empirical evidence for this potential? From Q4 2019 to Q3 2024, did infrastructure equity perform better during higher (CPI ≥ 4%) *vs.* lower (CPI < 4%) inflation periods? Figure 17 shows that infrastructure equity performance varied noticeably across inflation regimes. Certain sectors, such as Network Utilities and Transport, exhibited some of the most pronounced differences, with their quarterly returns increasing by more than a percentage point in higher-inflation *vs.* lower-inflation environments. In addition, infrastructure equity performed better than stocks (MSCI ACWI) and bonds (Bloomberg Global Aggregate), on average, during periods of higher inflation.

Figure 17: Average Quarterly Total Return (EDHEC Infrastructure Indices): Lower-Inflation Regime (CPI < 4%) *vs.* Higher-Inflation Regime (CPI ≥ 4%)

(Q4 2019 to Q3 2024, Gross of Mgmt. Cost)

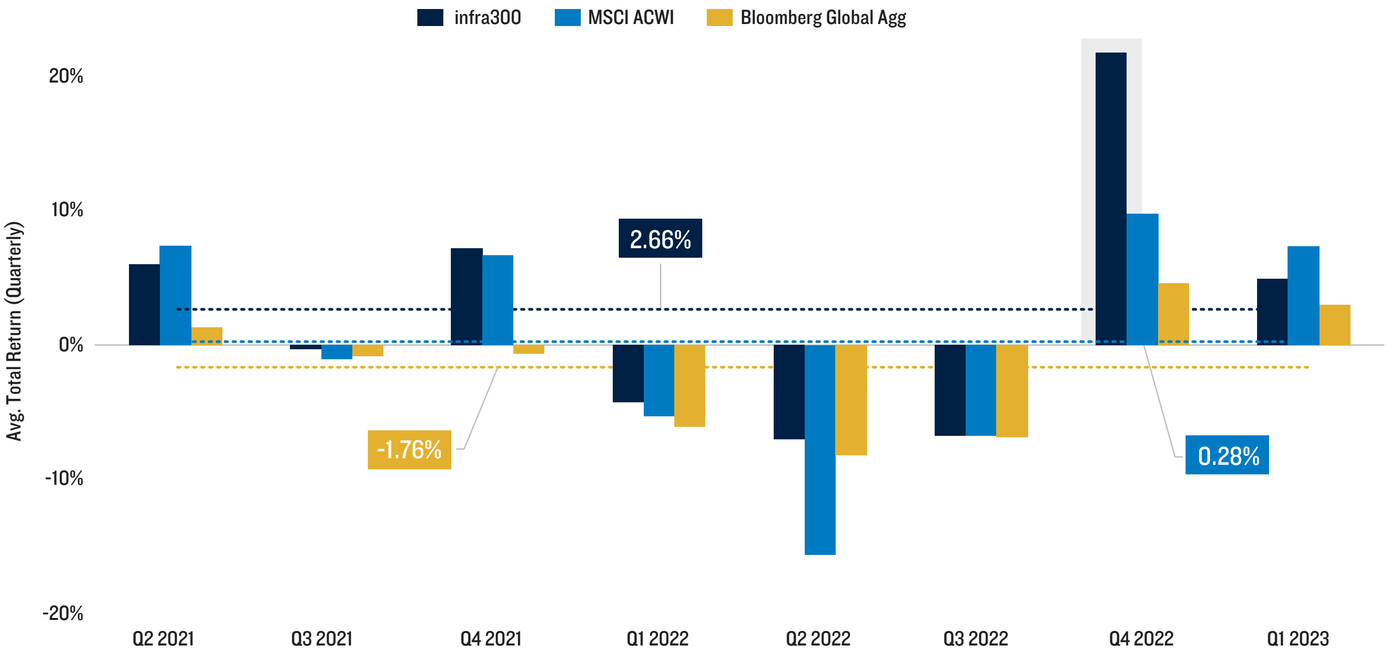


Note: Lower- (Higher-) inflation is defined US CPI year-over-year growth rate under (over) 4%. Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. Provided for illustrative purposes only. Please see Notice for important disclosures.

For the most recent inflationary period (Q2 2021 – Q1 2023; CPI ≥ 4%), how did infrastructure equity performed relative to public equities and bonds? On average, infrastructure equity (infra300) outperformed both public asset indices, suggesting that infrastructure assets offered some inflation protection during higher-inflation periods. A particularly strong infrastructure equity performance quarter occurred in Q4 2022, which was largely due to a reduction in equity risk premia driven by a smaller interest rate term spread and higher profitability (Figure 18). Even when excluding this exceptional quarter, infra300 still showed stronger relative performance, with an average quarterly return of -0.1%, compared to -1.1% for MSCI ACWI and -2.7% for Bloomberg Global Aggregate.

Figure 18: Average Quarterly Total Return in Higher-Inflation Periods (CPI ≥ 4%)

(Q2 2021 to Q1 2023, Gross of Mgmt. Cost)



Note: Lower- (Higher-) inflation is defined US CPI year-over-year growth rate under (over) 4%. Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. Provided for illustrative purposes only. Please see Notice for important disclosures.

Summary

Building on our earlier research on infrastructure portfolio construction, this paper leverages a new dataset to analyze infrastructure asset returns, distinguishing between price and income components, and identifying key return drivers such as sales growth and valuation multiple expansion or contraction.

We find that infrastructure assets tend to generate relatively high and stable income returns—typically around 4–5% per year, net of costs—which make up a large part of total return. This is especially notable compared to public equities, where returns are more heavily driven by price appreciation. We also clarify what "income return" means in the context of infrastructure, as this has sometimes confused investors.

We find that infrastructure investments carry significant asset-selection risk, underscoring the need for robust analytics that properly incorporate idiosyncratic risk for performance evaluation and allocation decisions.

Lastly, we compare infrastructure's performance with broader public markets and assess how inflation has influenced return dynamics. Infrastructure outperformed stocks and bonds during more inflationary periods, supporting its role as a potential inflation hedge.

Appendix

A1. Asset-level Infrastructure Equity Dataset

We use an asset-level infrastructure equity dataset from EDHEC*infra*, comprising approximately 900 historical (including 600 "live") unlisted infrastructure assets from EDHEC*infra*'s infraMetrics database as of April 2024. For each asset, the dataset provides annual indicative and financial metrics beginning from either (a) the asset's incorporation date or (b) the first year of available data obtained by EDHEC*infra* and continuing until the last financial reporting date for the asset. The metrics are categorized into four primary categories: **1) Asset Characteristics** (*e.g.,* asset age, sector classification, business risk, and corporate structure classification); **2) Cash Flow and Valuation metrics** (*e.g.*, dividends paid, shareholder loan interest, shareholder loan repayment, shareholder loan drawdown, and Equity Price); **3) Balance Sheet Measures** (*e.g.* Total Equity and Total Liability) and **4) Financial Ratios** (*e.g.,* EV/EBITDA, Price/Sales, EBIT Margin, Return on Equity). We further exclude assets older than 25y. Additionally, to mitigate the impact of extreme values, we remove metrics beyond the 98th percentile for income return, price return, earnings growth, sales growth, Price/Earnings (P/E), Price/Sales (P/S) ratios and P/E and P/S expansion and contraction. These filtering steps result in a refined subset of 657 assets, corresponding to 4,928 asset-year observations.

Not all assets in the dataset may have indicative and financial metrics simultaneously for a given year. For example, some assets may report financial information as of December year-end, while others may report earlier in the year. The dataset includes only an [asset-date] observation when the asset's financial information is reported. Since EDHEC*infra* reports a calculated price only at year-end, an EDHEC*infra* equity price is unavailable for an asset at non-financial reporting dates. Consequently, the dataset's incomplete time series coverage prevents calculating year-end to year-end returns consistent with the EDHEC*infra* Broadmarket index. To perform time-series analysis, we use the EDHEC*infra* Broadmarket Unlisted Infrastructure Equity index or "the infra300," rather than the infra dataset.

A2. *Pro Forma* Infrastructure Income Statement

a=b+c	**Operating Revenue**
b	Operation Revenue
c	Finance Interest Receivable*
d=e+f+g	**Operating Expense**
e	SG&A
f	Depreciation and Amortization
g	Other Operating Expense
h=a-d	***Operating Profit***
i=h+f	***EBITDA***

j=k+l+m	**Non-operating Revenue**
k	Construction Revenue
l	Extraordinary Revenue
m	Other Non-operating Revenue
o=p+q	**Non-operating Expense**
p	Interest Payable (*e.g.*, loan interest payable, shareholder loan interest payable)
q	Other Non-operating Expense
r=h+j-q	**EBIT (including non-operating revenue and non-operating expense)**

s=a+j-d-o	**Earnings Before Tax**
t	Tax
u=s-t	**Net Profit after tax (a.k.a. Net Income)**

Note: Finance Interest Receivable is associated with accounting treatment of availability payments. Availability payments(also known as unitary charge) are regular project payments made from the governmental entity to the private consortium once the piece of infrastructure is "available". According to accounting standards, financial reporting should reflect the economic substance of transactions rather than merely their legal form. As a result, availability payments need to be broken down according to economic substances of the arrangement and have correspondent recognition in the financial statements. Source: PGIM Multi-Asset Solutions. For illustrative purposes only.

A3. *Pro Forma* Infrastructure Cash Flow Statement

Cash Flow from Operations	Operating Profit after Tax (h-t from I/S)
	Cash from Operations (Reflecting depreciation and amortization (f on I/S), change in unearned Income (liability on B/S), change in receivables (asset on B/S), payables and prepayments(asset on B/S)
Cash Flow from Investing Activities	Change in Property, Plant and Equipment (Non-current asset on B/S)
	Change in Investments (Non-current asset on B/S)
Cash Flow from Financing Activities	***Dividends Paid*** (the prior year's retained earnings (part of Equity on B/S) + the current year's net income (u on I/S) – subtracting the current year's retained earnings)
	Shareholder Loan Interest (part of p from I/S)
	Repayment Shareholder Loans (part of Liability on B/S)
	Repayment of Debt (Senior Loans, Mezzanine Debt, Equity Bridge, Bonds) (part of Liability on B/S)
	Interest Expense (Senior Loans, Mezzanine Debt, Equity Bridge, Bonds) (part of p from I/S)
	Debt Drawdown (Senior Loans, Mezzanine Debt, Equity Bridge, Bonds) (part of Liability on B/S)
	Change in Equity (part of Equity on B/S)

Source: PGIM Multi-Asset Solutions. For illustrative purposes only.

A4. Handling of Reported *vs.* Extrapolated Financial Data in Asset Pricing

Unlike index-based datasets, which may include assets without recently reported financial data and rely on extrapolated past financials, our asset-level dataset only includes assets with reported financial data by the end of each period. For example, in an index, suppose an asset's last financing report was in June 2023 and no new data is available in December 2023, its equity risk premium would still be estimated using outdated financials ($\beta_{k,i,t-1}$) and new factor prices ($\lambda_{k,t}$) estimated using recent transactions in the infrastructure market. In contrast, our dataset ensures that valuations are based on actual reported financials and updated risk premia derived from recent market transactions. By limiting our dataset to assets with assets' actual financial characteristics, this approach provides a more realistic representation of infrastructure market performance and sector behavior, while still aligning closely with widely recognized benchmarks.

A5. Correlation: EDHEC Infrastructure Indices to Public Equity and Fixed Income

(Q4 2019 to Q3 2024, Gross of Mgmt. Cost)

In a higher-inflation regime (CPI ≥ 4%), correlations between infrastructure sub-sectors and public equities increase. Infrastructure equity's diversification benefits relative to equities can be more pronounced in low-inflation environments

Lower-Inflation Regime (CPI < 4%)

	infra300	Broadmarket	Network Utilities	Energy & Water Res.	Pwr Gen. x-Renew.	Renew. Pwr	Social Infra.	Transport	MSCI ACWI	Bloomberg Global Agg
infra300		1.00	0.95	0.94	0.97	0.96	0.91	0.96	0.53	0.83
Broadmarket			0.95	0.94	0.96	0.97	0.90	0.96	0.54	0.84
Network Utilities				0.83	0.89	0.95	0.92	0.84	0.45	0.81
Energy & Water Res.					0.95	0.85	0.81	0.95	0.35	0.80
Pwr Gen. x-Renew.						0.89	0.79	0.97	0.51	0.74
Renew. Pwr							0.92	0.89	0.59	0.85
Social Infra.								0.76	0.44	0.93
Transport									0.55	0.72
MSCI ACWI										0.40
Bloomberg Global Agg										

Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. For illustrative purposes only.

Higher-Inflation Regime (CPI ≥ 4%)

	infra300	Broadmarket	Network Utilities	Energy & Water Res.	Pwr Gen. x-Renew.	Renew. Pwr	Social Infra.	Transport	MSCI ACWI	Bloomberg Global Agg
infra300		1.00	0.97	0.96	0.98	0.99	0.98	0.98	0.85	0.89
Broadmarket			0.96	0.96	0.96	1.00	0.99	0.99	0.86	0.88
Network Utilities				0.89	0.97	0.94	0.95	0.92	0.87	0.88
Energy & Water Res.					0.90	0.96	0.96	0.94	0.85	0.83
Pwr Gen. x-Renew.						0.94	0.91	0.93	0.79	0.85
Renew. Pwr							0.98	0.99	0.84	0.86
Social Infra.								0.97	0.89	0.87
Transport									0.82	0.87
MSCI ACWI										0.94
Bloomberg Global Agg										

Source: PGIM Multi-Asset Solutions, EDHEC*infra*, Datastream. For illustrative purposes only.

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