PGIM
MULTI-ASSET SOLUTIONS

INCOME RETURNS OF INFRASTRUCTURE

Model Specification & Estimation

April 2025

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Institutional investors are increasingly considering unlisted infrastructure due to its potential total returns, diversification benefits and potential for more consistent income returns compared to other illiquid private asset classes. Supply has increased commensurately with growing demand as the unlisted market has grown significantly – since 2015 at a CAGR of 19.7% for a total of $1.2t by March 2023, almost three times the pace of overall global AUM growth. To optimize infrastructure's integration into asset allocation it is important to quantify and model the components of infrastructure asset returns – both price and income returns.

Unlisted infrastructure equity asset-level income and price returns exhibit distinct dynamic behavior in terms of systematic factors such as sensitivity to both public market performance and the asset's characteristics (*e.g.* age, sector, *etc.*), as well as idiosyncratic behavior.[1] In 2022, we introduced an approach to model infrastructure equity asset-level income and price returns separately to better capture these dynamics.

Since then, we have acquired a new infrastructure equity asset-level time series "dataset" from EDHEC*infra*.[2] This dataset contains detailed asset-level financial attributes (*e.g.* profitability measures, valuation ratios, *etc.*), in addition to cash flows and valuations observations. The dataset allows us to test and refine our modelling of income returns and examine our parameter estimation process in more detail. We remain confident that our modeling approach is fit-for-purpose.

We review the key components of our infrastructure equity income return models and how they capture the unique characteristics of this asset class. Additionally, we examine our model parameter estimation procedures, comparing frequentist and Bayesian estimation approaches.

> With the availability of an updated dataset, we examine our infrastructure equity asset-level income return model. This model aims to assist investors in integrating infrastructure into their portfolios, seeking to enable a more precise evaluation of infrastructure's potential role in contributing to stable income returns, diversification benefits and portfolio liquidity.

1 See our companion paper, *Direct Infrastructure Equity: Performance, Return Attribution, & Inflation Resilience,* A. Chen and J. Shen, *forthcoming 2025, PGIM Multi-Asset Solutions*, for details on our infrastructure equity asset total return attribution methodology.

2 See companion paper for details on the asset-level dataset.

Infrastructure Equity Asset Total Return Attribution

When evaluating asset performance it is useful to decompose total returns into their income and price return components.

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

What has been the source of total returns: valuation changes or income? Some argue that infrastructure assets offer stable, long-term, income returns. Moreover, infrastructure assets' (supposedly ample) income returns might play a crucial role in meeting portfolio liquidity needs, such as to support pension liability payments. By isolating an asset's income returns from price returns, investors can gain insights into the nature of an asset's total returns which may enable a more precise alignment of the investment's cash flow characteristics with a portfolio's investment objectives.

As described in our companion paper, it is tricky to differentiate between an infrastructure asset's true income return and commonly-reported cash return. Since infrastructure shareholder equity is a stapled bundle of common equity *and* shareholder loans, cash outflow arising from loan drawdowns (a disbursement of capital from the equity investor) and cash inflows back to the equity investor arising from shareholder loan *principal repayments* (Figure 1) should not be considered part of the asset's income return. Some data providers include these cash flows in their definition of the asset's "cash return."[3] The difference between an asset's cash and income return can be substantial. Only the asset's income return is germane for total return attribution to help investors make better informed portfolio allocation decisions.

Figure 1: Cash Inflows and Outflows of Infrastructure Equity Investments – From Shareholder's Perspective

From Shareholder's Perspective	Infrastructure Equity	
	Common Equity	Shareholder Loans
Cash Inflow	Dividends	Shareholder Loan Interest Payments
		Shareholder Loan Repayments
Cash Outflow	Paid in Capital (Cash Investment)	Shareholder Loan Drawdowns

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

Specifically, price return reflects changes in the total equity value of the infrastructure asset (both common equity and shareholder loans). Income return refers to earnings generated from the asset, including equity dividends and shareholder loan interest income. Note that any shareholder loan repayments during the period are not part of income return as we consider loan repayments as return of capital, rather than earnings or yield on the investment.

$$Price\ Return_t = \frac{Ending\ Total\ Infra\ Equity\ Value_t}{Ending\ Total\ Infra\ Equity\ Value_{t-1}} - 1$$

$$Income\ Return_t = \frac{Dividends_t + Shareholder\ Loans\ Interest_t}{Ending\ Total\ Infra\ Equity\ Value_{t-1}}$$

Our focus is on infrastructure equity *asset* performance, not infrastructure *fund* performance.[4] Fund performance measures (*e.g.,* IRRs, multiples and PMEs) rely on interim GP-reported valuations (NAVs) which complicates direct comparison with *asset* performance that uses a "fair market value" valuation method. Quarterly IRRs typically exhibit serial correlation and lag public asset "mark-to-market" valuation changes, particularly when public asset values decline sharply. In addition, while interim *asset* "mark-to-market" valuation reflects market gains/losses, interim *fund* valuation includes inflows of further contributions and/or outflows of distributions from dispositions and/or income, in addition to GP markups/markdowns of the portfolio assets. Consequently, for portfolio construction, infrastructure asset and fund investments need different treatment both in terms of performance measurement and cash flow characteristics – to capture the distinct features associated with the different investment vehicles.

3 EHDEC*infra*'s definition of "cash return" (or "cash yield") includes shareholder loan principal repayments along with shareholder loans interest payments and dividends paid to common equity investors. *The Scientific Infra and Private Assets Unlisted Equity Infrastructure Indices Methodology* (Scientific Infra & Private Assets, 2020). https://docs.scientificinfraprivateassets.com/docs/equity-unlisted-equity-index-methodology.

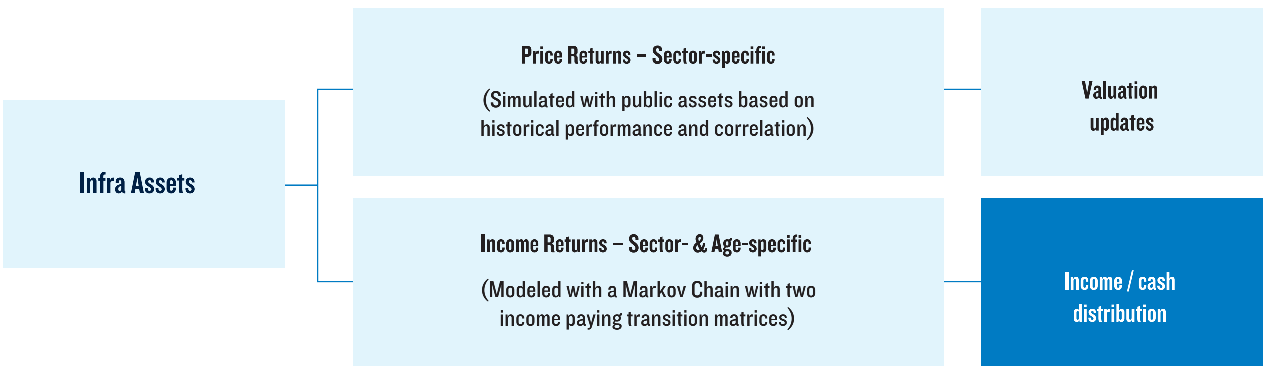
4 We use the Takahashi and Alexander (TA) model to estimate unlisted infrastructure equity fund valuations (*i.e.*, NAVs) and cash flows (*i.e.*, contributions and distributions) for each vintage year commitment.

When constructing portfolios with infrastructure, it is critical to distinguish asset-level income returns from fund-level cash returns (commonly known as the fund's distribution yield). The former includes common dividends and shareholder loan interest payments while the latter reflects all cash flows returned to investors, including proceeds from asset sales and the return of capital from shareholder loan principal repayments.

Modeling Infrastructure Equity Asset Income Returns

On average, *at the sector-level*, infrastructure equity can provide relatively stable income returns, with low sensitivity to public market performance, while price returns are volatile and tend to be positively correlated with public equity performance. In addition, although within a sector there is large cross-sectional volatility in both income and price returns, price returns exhibit much higher idiosyncratic risk compared to income returns. As a result, we model price and income returns separately for infrastructure assets, given their distinct asset-level characteristics (Figure 2).[5]

Figure 2: Modeling Unlisted Infrastructure Equity Income and Price Returns



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

An infrastructure asset's income return depends on its age, sector (and its associated business risk and corporate structure) and idiosyncratic behavior.[6] Figure 3 shows that annual income returns have differed significantly across sectors. We find that *Power Generation x-Renewables* and *Renewable Power* assets have generated relatively high income returns: 9.2%/y and 8.1%/y, respectively. These are generally contracted project assets from which the asset owner receives a fixed payout (income) at regular intervals based on specific service level agreements. *Network Utilities* assets – typically natural monopoly assets regulated to ensure operations at a reasonable cost to end users – have generated an income return of around 6.7%/y. *Social Infrastructure* and *Transport* assets have generated relatively lower income returns compared with other sectors, 6.2%/y and 5.6%/y, respectively.

5 For details on our infrastructure asset price return model, please see *Building Portfolios with Infrastructure: Performance, Cash Flows & Portfolio Allocation*, J. Shen & F. Blanc-Brude, PGIM and EDHEC*infra*, 2022. Unlike infrastructure equity asset income return, price returns demonstrate high volatility in both lifespan and cross-sectional dimensions. Additionally, although sector-wise infrastructure equity assets price returns are sensitive to public assets performance, asset-level price returns are idiosyncratic and unexplained by the systematic factors such as asset's financial characteristics or public assets performance. As a result, despite the access to the infrastructure asset-level dataset, we decided not to examine our earlier price return model further.

6 We introduced infrastructure equity assets income return modeling in *Building Portfolios with Infrastructure: Performance, Cash Flows & Portfolio Allocation*, J. Shen & F. Blanc-Brude, PGIM and EDHEC*infra*, 2022.

Figure 3: Infrastructure Equity Annual Income Return and Volatility, by Sector, %y (2007 – 2022, Gross of Mgmt. Cost)

Sector	Count	Expected Annual Income Return	Lifespan Annual Income Return Volatility	Cross-sectional Annual Income Return Volatility	Total Income Return Volatility
Power Generation x-Renewables	94	9.2%	3.2%	9.9%	11.2%
Environmental Services	22	9.1%	3.3%	7.5%	9.9%
Energy and Water Resources	41	8.4%	2.0%	7.1%	8.4%
Renewable Power	151	8.1%	1.9%	8.9%	9.2%
Network Utilities	72	6.7%	2.0%	6.0%	6.3%
Social Infrastructure	72	6.2%	2.0%	5.3%	5.8%
Transport	185	5.6%	1.4%	7.5%	7.7%
Data Infrastructure	23	3.9%	4.0%	4.8%	6.8%

TICCS Business Risk	Count	Expected Annual Income Return	Lifespan Annual Income Return Volatility	Cross-sectional Annual Income Return Volatility	Total Income Return Volatility
Contracted	390	7.5%	1.7%	8.6%	8.8%
Merchant	162	6.1%	1.4%	8.2%	8.6%
Regulated	108	6.3%	1.7%	6.6%	6.6%

TICCS Corporate Structure	Count	Expected Annual Income Return	Lifespan Annual Income Return Volatility	Cross-sectional Annual Income Return Volatility	Total Income Return Volatility
Corporate	168	6.3%	1.1%	7.1%	7.1%
Project	492	7.2%	1.4%	8.7%	8.8%

Age Group	Count	Expected Annual Income Return	Lifespan Annual Income Return Volatility	Cross-sectional Annual Income Return Volatility	Total Income Return Volatility
Greenfield	105	6.8%	1.2%	7.4%	7.4%
Operating	391	6.0%	0.5%	7.3%	7.5%
Brownfield	543	6.9%	0.7%	8.3%	8.4%
Mature	250	8.8%	0.4%	9.8%	9.8%

Note: The Infrastructure Company Classification Standard or TICCS is a taxonomy designed to classify and organize data about equity and debt investments in infrastructure companies, created by EDHEC*infra*. It consists of four pillars: business risk, industrial activity, geo-economic exposure and corporate structure. Source: PGIM Multi-Asset Solutions, EDHEC*infra*. For illustrative purposes only.

Figure 3 shows that infrastructure assets, on average, have displayed relatively low *lifespan* (or *index-level*, or time series) income return volatility which captures the variability of the asset's expected income return over its lifespan, but very high *cross-sectional* (or *idiosyncratic*) income return volatility which accounts for the asset's income returns varying from the population of similar assets, even within a sector.[7] For a CIO, this presents high asset *selection risk*: since the available selection of infrastructure assets is often limited at a time, the CIO has a high risk of selecting an asset whose income return differs substantially from the average income return of the overall asset class or sector.

So, when allocating to direct infrastructure a CIO must consider both an asset's *lifespan* income return volatility and the asset's *cross-sectional* income return volatility. Our income return model – which is estimated using actual asset-level income returns – incorporates both time series volatility and cross-sectional volatility and, thus, better reflects the income return behavior of direct infrastructure equity assets.

Infrastructure asset income returns also typically demonstrate path-dependency, *i.e.*, if the asset has a positive income return during this period, it is more likely than not to have a positive income return next period, and the level of income return is likely to be highly correlated with the prior period's level of income return. (This explains why an asset's lifespan income return volatility tends to be small).

To capture the nature of path dependency of infrastructure equity asset's income return (or low lifespan income return volatility), we use a Markov modeling approach whereby an infrastructure asset's expected quarterly income return depends only on the asset's prior period income return. There are two steps involved in our income return model:

Step 1: Determine **if** income return is positive in each year over the asset's lifetime;

Step 2: If income return is positive in a year, determine **the quartile** of the sector-specific income return distribution from which to draw the quarterly income return; and

To reflect the cross-sectional idiosyncratic risk of infrastructure equity income returns, we follow **Step 3** below to determine an asset's annual income return:

Step 3: If income return is positive in a year, randomly draw the annual income return from the appropriate quartile selected in Step 2.

Together, these three steps estimate an infrastructure asset's future quarterly income return.

The income return model involves two "transition matrices" that describe an asset's income return behavior *every period*, based on the asset's income return behavior in the *preceding period*. The first transition matrix (Step 1) determines *if* an asset will pay income this period whereas the second transition matrix (Step 2) determines the *magnitude* of the asset's income return this period.

Using the infrastructure asset-level **dataset** – with its age group and sector detail – we estimate the two "transition matrices" using **two approaches** – Bayesian and frequentist. Bayesian estimation is now widely used in private asset price estimation where data are limited. Besides updating our income return model with the updated dataset, we take the opportunity to evaluate if the two estimation approaches produced sharply different parameter estimates.

Dealing with Limited Data – Comparison between Frequentist & Bayesian Estimation Approaches

A **frequentist** statistical inference approach draws conclusions from the sample data by calculating the long-run frequency (or probability) of an event having occurred in the past. In comparison, a **Bayesian** approach is a methodology that iteratively updates probabilities based on data and past prior beliefs (in the form of a probability distribution of the parameter). A prior probability distribution, p(π), – or simply "the prior" – summarizes the initial beliefs about a parameter (transition probability π) before new data are obtained.[8] As more data become available, the probability about a parameter (also known as the "posterior" distribution) is updated using Bayes' Theorem:

$$P(\pi|\text{data}) = \frac{P(Data|\pi) \bullet p(\pi)}{p(data)}.$$

An advantage of the Bayesian approach is its ability to incorporate the investigator's prior knowledge – when we have strong prior beliefs, it takes highly compelling evidence to shift those beliefs, while when we are less certain about our prior, the data play a stronger role in shaping the inference. This approach seems quite reasonable especially when an asset class is relatively new which is often the case for illiquid private assets. The Bayesian approach provides a way to integrate prior knowledge with the available evidence, whereas the frequentist approach might struggle to produce reliable estimates due to insufficient sample size.

7 Lifespan income return volatility ($\sigma_{lifespan}$) is calculated as the volatility of average annual income returns over ages t: $\sigma(Average\ Annual\ Income\ Return_t)$; Cross-sectional income return volatility ($\sigma_{cross-sectional}$) is calculated as the average of cross-sectional volatility of individual asset i's annual income returns over ages: $E\left(\sigma\left(\text{Average Annual Income Return}_i\right)_t\right)$; $\sigma_{total} = \sqrt{Var_{cross-\widehat{sectional}} + Var_{lifespan}}$.

8 For example, π_{00} is the probability of staying at zero income return state and π_{11} is the probability of staying at positive income return state.

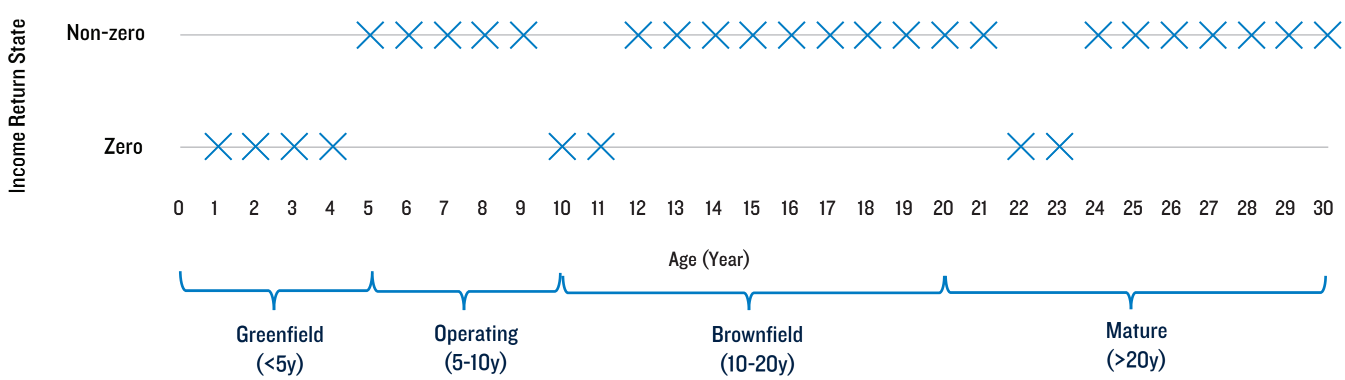
However, as discussed in our companion paper, the Bayesian approach has several limitations. First, forming reliable Bayesian estimates at the beginning of the data collection period can be challenging, raising questions on how much transaction data are needed to reliably update the investigator's prior. The frequentist approach, while not requiring a prior, can also be unstable with limited data. Second, Bayesian inference is sensitive to the assumed prior, which influences the speed at which estimates converge as data become available. Depending on the choice of priors, significantly more or fewer data points may be required to reach stable estimates. On the other hand, the frequentist approach relies exclusively on data for inference, avoiding the potential subjectivity introduced by priors. Finally, the effectiveness of Bayesian methods can be limited in the presence of *regime shifts*, as prior distributions constrain how quickly new data update the estimates. If the regime changes significantly, Bayesian updating may require substantial additional observations before reflecting the new reality.[9] In comparison, the frequentist approach, while not tied to an out-of-date prior, will also need time for sufficient data to generate a robust parameter estimate.

Infrastructure Equity Asset Income Returns – Parameter Estimation

Step 1 – Estimating the annual Zero *vs.* Non-zero Income Return State Transition Matrix

Figure 4 illustrates a hypothetical sequence of Zero/Non-zero income return states over the lifespan of an infrastructure equity asset – Step 1. As shown, this asset happens to begin its life in a zero income return state. By year 5 it begins to persistently generate positive income return. Nevertheless, as the asset ages it may occasionally fail to produce a positive income return in a year, and this Zero income return state could persist for a year or two (or more).

Figure 4: Income Return States for a Hypothetical Infrastructure Asset



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

Figure 5 shows the Annual Zero *vs.* Non-zero Income Return State Transition matrix that powers the path of income return state of an infrastructure equity asset over its lifespan. There is a separate matrix for each age group – *Greenfield, Operating, Brownfield* and *Mature*.[10] The cells are the probabilities of transitioning from a preceding year's income return state (indicated by row) to either Zero or Non-zero income return state in the current year (column).

Figure 5: Annual Zero *vs.* Non-zero Income Return State Transition Matrix (by Age Group) – Estimated with Frequentist Approach

Age Group	Greenfield (<5y)		Operating (6-10y)		Brownfield (11-20y)		Mature (>20y)	
From \ To	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero
Non-Zero	95%	5%	95%	6%	96%	4%	96%	4%
Zero	13%	88%	28%	72%	20%	80%	26%	74%

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

9 There are approaches that allow Bayesian updating to adapt more quickly to new data. For example, exponentially weight past observations with a decay factor, reducing their influence over time or adopting nonparametric Bayesian methods.

10 Based on historical data, we do not find the transition probabilities depend on the economy, nor are they much different across sectors.

The Figure 5 transition matrix is estimated with the **frequentist approach**. In Figure 6, each cell represents observed transitions between income return states (Non-zero and Zero) for different age groups. For example, we observe 78 occurrences of brownfield assets that had positive income return in the prior year transitioning from a positive income return state to a zero income return state in the current year, and 1,772 occurrences of brownfield assets staying at a positive income return state. With maximum likelihood estimation (MLE), if a brownfield infrastructure asset generated positive income return during the preceding year, the estimated probability that it will produce zero income return this year is 78/(78 + 1,772) = 4.2% and the probability that it will keep generate positive income return this year is 1,772/(78+1,772) = 95.8%.[11]

Across age groups, once an asset has generated income, it has tended to continue generating positive income return for the next period. On the other hand, it has tended to stay in the Zero income return state, although such likelihood falls as asset becomes more mature – the probability of staying at Zero income return state decreases from 88% for a Greenfield asset to 74% for a Mature asset.

Figure 6: Annual Zero *vs.* Non-zero Income Return State Transition Occurrences (by Age Group)

Age Group	Greenfield (<5y)		Operating (6-10y)		Brownfield (11-20y)		Mature (>20y)	
From \ To	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero
Non-Zero	52	3	567	33	1,772	78	567	22
Zero	2	14	58	147	97	397	31	89

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

The Annual Zero *vs.* Non-zero Income Return State Transition matrices can also be estimated using a **Bayesian approach**. Before observing any data, we form our prior transition probabilities that have beta distributions with the following mean and standard deviation assumptions. Figure 7 reflects our hypothesis that the probability of staying at a Non-zero income return state is high (persistent income paying) and gradually increases as asset matures. In addition, the probability of staying at Zero income return state is also high but gradually decreases as asset matures. Figure 8 shows our standard deviation assumptions of the beta priors. [12]

Figure 7: Annual Zero *vs.* Non-zero Income Return State Transition Matrix (by Age Group) – Bayesian Prior – Mean

Age Group	Greenfield (<5y)		Operating (6-10y)		Brownfield (11-20y)		Mature (>20y)	
From \ To	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero
Non-Zero	85%		90%		90%		95%	
Zero		85%		80%		75%		70%

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

Figure 8: Annual Zero *vs.* Non-zero Income Return State Transition Matrix (by Age Group) – Bayesian Prior – Standard Deviation

Age Group	Greenfield (<5y)		Operating (6-10y)		Brownfield (11-20y)		Mature (>20y)	
From \ To	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero
Non-Zero	10%		10%		10%		10%	
Zero		10%		10%		10%		10%

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

11 An example of estimating transition probabilities of a brownfield asset from a Non-zero income return state using MLE (frequentist approach) is shown in Appendix B.

12 Shape parameters α and β are derived from beta mean (μ) and standard deviation (σ) assumptions with the following formula:
$\alpha = -\frac{\mu(\sigma^2+\mu^2-\mu)}{\sigma^2}$ and $\beta = \frac{(\mu-1)(\sigma^2+\mu^2-\mu)}{\sigma^2}$. In order for the problem to be meaningful μ must be between 0 and 1, and σ^2 must be less than $\mu(1-\mu)$.

Figure 9 illustrates the Bayesian iterative annual updating process for estimating the probability of a brownfield asset staying at a Non-zero income return state using data from 2007 to 2022.[13] The first column indicates the number of assets whose income return state in the prior year is Non-zero (positive), while the second column shows the number of observed transitions where assets remained in the positive income return state in the current year. For example, in 2007 there were only two observed transitions with both assets staying in the positive income paying state. After incorporating the new data with the 90% prior estimate for brownfield assets staying in the positive income return state, the updated (posterior) Bayesian estimate for the probability increases to 92%, with a standard deviation of ~8%. This in turn becomes the new prior for 2008. Similarly, in 2008, with new observations added (62 out of 65 assets staying in the positive income paying state), expected posterior Bayesian probability was updated to 95% and the standard deviation further narrowed to 2.5%, reflecting reduced uncertainty due to the increased sample size. By 2022, the expected posterior Bayesian probability converged to 96%, aligning with the frequentist estimate of 96%. The standard deviation further decreased to 0.5%, illustrating the increased stability of the estimates as more data became available.

Figure 9: Brownfield Asset Income Return State Transition Observations (Non-zero to Non-zero) and Bayesian Transition Probability Estimates

Year	Positive Income Return State (Last Year)	# of Data Obs Staying in Positive Income Paying State	Expected Transition Probability (Bayesian Approach)	Transition Probability Standard Deviation (Bayesian Approach)	Transition Probability (Frequentist Approach)
2007	2	2	92%	8%	100%
2008	65	62	95%	3%	96%
2009	63	58	94%	2%	94%
2010	83	76	93%	2%	93%
2011	110	104	93%	1%	93%
2012	122	118	94%	1%	94%
2013	136	130	95%	1%	95%
2014	135	132	95%	1%	95%
2015	148	145	96%	1%	96%
2016	159	156	96%	1%	96%
2017	173	162	96%	1%	96%
2018	160	153	96%	1%	96%
2019	162	156	96%	1%	96%
2020	143	135	96%	0%	96%
2021	118	114	96%	0%	96%
2022	71	69	96%	0%	96%

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

Figure 10 shows Annual Zero *vs.* Non-zero Income Return State Transition Matrix (mean) estimated with the Bayesian approach. Except for the greenfield age group, transition probability estimations are very close to estimations using the frequentist approach (Figure 5). There are limited data observations for the greenfield age group – only 55 observations transitioning from a Non-zero income return state and 16 observations transitioning from a Zero income return state from 2007 to 2022 (Figure 6). This leads to the expected Bayesian transition probability estimates that are slightly different from frequentist estimates for this age group. For example, the posterior probability of staying at a Non-zero income return state follows a beta distribution with a mean of 93% (and a standard deviation of 3%, not shown); the posterior probability of staying at a Zero income return state follows a beta distribution with a mean of 86% (and a standard deviation of 6.4%).

13 Appendix C shows how we estimate the transition probabilities of an asset from a Non-zero income return state of the preceding period to Zero income return state of the current period using Bayesian estimation.

Figure 10: Annual Zero *vs.* Non-zero Income Return State Transition Matrix (by Age Group) – Estimated with Bayesian Approach

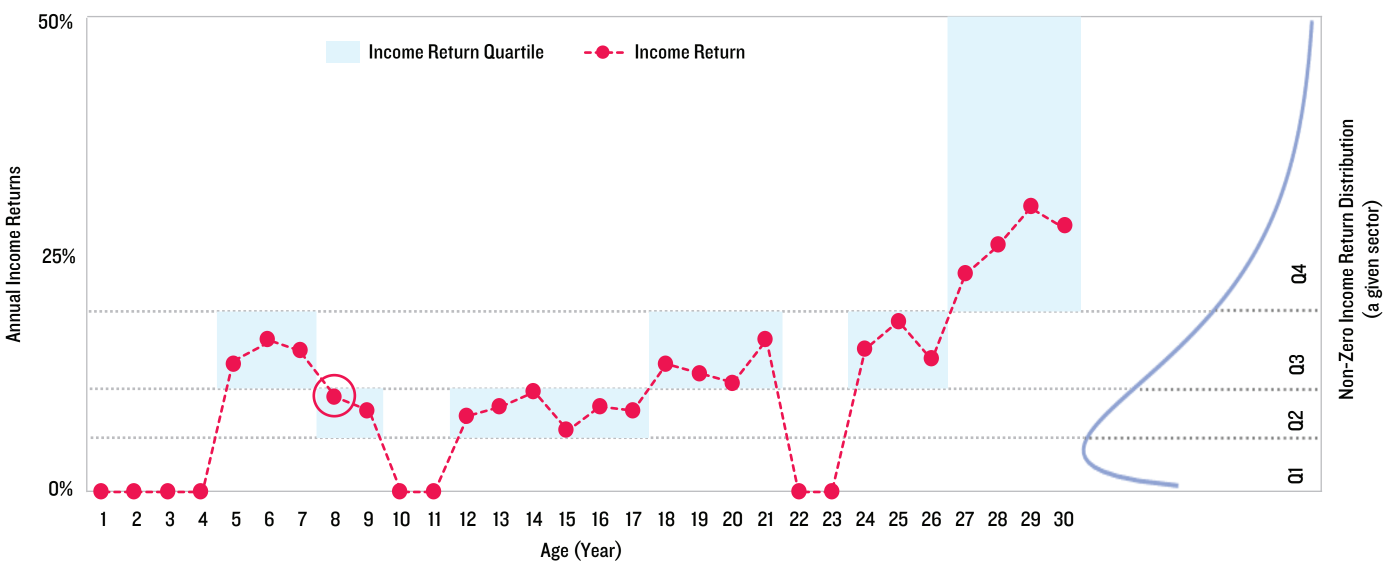
Age Group	Greenfield (<5y)		Operating (6-10y)		Brownfield (11-20y)		Mature (>20y)	
From \ To	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero	Non-zero	Zero
Non-Zero	93%	7%	94%	6%	96%	4%	96%	4%
Zero	14%	86%	28%	72%	19%	81%	25%	75%

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

Step 2&3 – Estimating Annual Income Return Quartile (in a Non-Zero State) Transition Matrix

If an infrastructure asset is generating positive income return in a year (determined by Step 1), we then need to determine "how much?" To do so, we first examine historical sector income returns and identify quartiles. Figure 11 illustrates a hypothetical asset's transition of income return quartile and its annual modelled income return over its life. The right side of Figure 11 shows a right-skewed Non-zero income return distribution, for a given sector, partitioned into its four quartiles.[14] Each quartile has a range of income returns. At each period of evaluation, the model selects an income return quartile for each infrastructure asset (light, blue-shaded bars) based on the probabilities from the annual income return quartile transition matrix (by sector) estimated below (Step 2). Finally, we randomly sample a specific income return from the Step 2-selected income return quartile (Step 3). For example, see the red circle for year 8 in Figure 11. For this example, the asset in year 8 has a positive income return drawn from Q2. This process is repeated for this and all years forward, producing a series of red dots connected by the dashed line in Figure 11.

Figure 11: Hypothetical Asset Lifespan Income Return (and Quartile) Sequence



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

Figure 12 shows an asset's annual income return quartile transition matrix, by sector, estimated with the frequentist approach. The values in the cells indicate the probabilities of transitioning from a preceding year's income return quartile (indicated by the row) to a quartile (ranging from Q1 (bottom) to Q4 (top)) for the current year (column). For example, if a *Transport* asset generated top quartile (Q4) income return in the preceding year, there is a 67% probability it will produce a top quartile (Q4) income return this year and a 24%, 5%, and 4% chance, respectively, of switching to Q3, Q2, and Q1 income return (see red rectangle). Figure 12 indicates that an asset's income return this year has often remained in the same income return quartile as the preceding year (see the shaded diagonal values) – indicating some persistence in the level of income return for an infrastructure asset. This empirical pattern matches investors' intuition.

14 The Non-zero income return histograms (by sector) based on data from 2007 to 2022 from the infrastructure asset-level dataset are presented in Appendix D1. Additionally, we also fit sector-specific income return distributions (positive skewed) as beta distributions (continuous probability distributions defined on the interval [0, 1] controlled by two shape parameters, alpha (α) and beta (β)). Appendix D2 provides the beta distribution parameters.

Figure 14 shows an asset's annual income return quartile transition matrix (mean), by sector, estimated with the Bayesian approach using the prior shown in Figure 13 before the transition matrices were updated with data.[15] After updating the priors iteratively using data from 2007 to 2022, the sector-specific income return quartile transition matrix estimates (Figure 14) are close to those using the frequentist approach (Figure 12). The expected transition probability of any quartile, or of any sector, is within ±3%, except for Environmental Services and Data Infrastructure (in total 92 and 60 quartile transition observations, respectively, from 2007 to 2022, compared with over hundreds of observations for the other sectors).[16]

Figure 12: Annual Income Return Quartile (in a Non-Zero State) Transition Matrix, by Sector – Estimated with Frequentist Approach

	Power Generation x-Renewables				Social Infrastructure				Transport			
	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	58%	26%	9%	7%	70%	18%	9%	4%	67%	24%	5%	4%
Q3	21%	51%	27%	1%	22%	42%	27%	9%	18%	47%	28%	8%
Q2	11%	22%	50%	17%	7%	25%	46%	22%	10%	23%	53%	14%
Q1 - Bottom	5%	9%	13%	73%	2%	12%	17%	69%	4%	6%	16%	74%

	Environmental Services				Renewable Power				Network Utilities			
	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	55%	25%	10%	10%	59%	25%	13%	3%	51%	30%	11%	8%
Q3	16%	48%	28%	8%	24%	51%	20%	5%	27%	36%	32%	6%
Q2	23%	19%	42%	15%	8%	20%	50%	21%	6%	24%	49%	21%
Q1 - Bottom	10%	19%	24%	48%	5%	4%	14%	77%	10%	7%	12%	71%

	Energy and Water Resources				Data Infrastructure			
	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	64%	22%	6%	8%	50%	36%	7%	7%
Q3	17%	49%	26%	8%	17%	33%	42%	8%
Q2	7%	24%	46%	24%	18%	18%	29%	35%
Q1 - Bottom	13%	7%	20%	61%	6%	0%	29%	65%

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

Figure 13: Annual Income Return Quartile (in a Non-Zero State) Transition Matrix – Bayesian Prior, Mean and Standard Deviation

	Beta Mean			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	60%	25%	12%	3%
Q3	22%	50%	18%	10%
Q2	12%	20%	50%	18%
Q1 - Bottom	9%	13%	18%	60%

	Beta Standard Deviation			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	10%	10%	10%	10%
Q3	10%	10%	10%	10%
Q2	10%	10%	10%	10%
Q1 - Bottom	10%	10%	10%	10%

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

15 The mean of the prior Beta distribution is assumed such that the probability of staying at respective quartile is the highest (>50%).

16 In Appendix E we provide Bayesian estimates of the Annual Income Return Quartile Transition matrix (by sector) using an alternative prior assumption – specifically, a smaller Beta standard deviation (5% compared to 10% in Figure 13). A prior with low standard deviation (or variance) reflects high confidence in the prior beliefs about the transition probability. As a result, the observed data will have a smaller impact on the final posterior estimation. Compared to Figure 14, the average Annual Income Return Quartile Transition matrix (by sector) estimates in Appendix E are closer to the prior's mean than to the estimation by the frequentist approach.

Figure 14: Annual Income Return Quartile (in a Non-Zero State) Transition Matrix, by Sector – Estimated with Bayesian Approach

	Power Generation x-Renewables			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	59%	26%	9%	6%
Q3	22%	50%	26%	2%
Q2	11%	22%	50%	17%
Q1 - Bottom	7%	9%	14%	70%

	Social Infrastructure			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	68%	19%	9%	4%
Q3	22%	43%	26%	9%
Q2	7%	24%	47%	21%
Q1 - Bottom	3%	12%	18%	68%

	Transport			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	66%	24%	5%	5%
Q3	18%	47%	27%	8%
Q2	11%	23%	53%	14%
Q1 - Bottom	5%	7%	16%	72%

	Environmental Services			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	58%	25%	11%	7%
Q3	18%	49%	24%	8%
Q2	18%	20%	46%	16%
Q1 - Bottom	7%	17%	22%	54%

	Renewable Power			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	59%	25%	13%	3%
Q3	24%	51%	20%	5%
Q2	9%	20%	50%	21%
Q1 - Bottom	6%	5%	15%	74%

	Network Utilities			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	53%	29%	11%	7%
Q3	25%	39%	30%	6%
Q2	7%	24%	49%	21%
Q1 - Bottom	11%	8%	13%	68%

	Energy and Water Resources			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	63%	23%	7%	8%
Q3	18%	49%	25%	8%
Q2	7%	23%	47%	23%
Q1 - Bottom	13%	8%	19%	61%

	Data Infrastructure			
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	56%	30%	9%	5%
Q3	18%	44%	29%	9%
Q2	12%	19%	41%	28%
Q1 - Bottom	9%	5%	24%	62%

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

Bayesian estimation provides the full posterior distribution of the annual income return quartile transition probability, which includes uncertainty measures such as standard deviation. For sectors with a high number of transition observations, the posterior variability is significantly reduced from the initial prior assumption (10%). For example, the Transport sector has approximately 186 observations from 2007 to 2022 transitioning from Q1, the posterior standard deviation of Q1→Q1 transition probability is reduced to 3%. Similarly, the Renewable Power sector has approximately 157 observations from 2007 to 2022 transitioning from Q3, reducing the posterior standard deviation of Q3→Q3 transition probability to 3.7%. In contrast, Data Infrastructure had only 14 data observations from 2007 to 2022 transitioning from Q4, so the posterior standard deviation of Q4→Q4 transition probability is only reduced to 8%.

The Bayesian estimation of the annual income return quartile transition matrices highlights the relationship between the number of transition observations and the posterior variability and shows the impact of data availability on the reliability of Bayesian estimates.

Our comparison between frequentist and Bayesian estimation does not conclude that one approach is inherently superior to the other – rather, the choice depends on the way we interpret uncertainty and the decision-making context. A purely data-driven approach (frequentist) may work well when data is abundant and stable, but in dynamic environments, incorporating *well-reasoned* priors can lead to more robust insights. The key is to strike a balance between objectivity and informed judgement, ensuring quantitative estimates remain both rigorous and practical.

CIO Takeaways

- **We suggest there has been persistence in the income return for an infrastructure asset over its lifetime. Once an infrastructure asset has generated income, it has tended to continue generating positive income. In addition, an asset's income return in a given year has often remained in the same income return quartile as the preceding year.**
- **Our asset-level income return model aims to assist investors in integrating infrastructure into their portfolios, seeking to enable a more precise evaluation of infrastructure's potential role in contributing to stable income returns, diversification benefits and portfolio liquidity.**
- **When analyzing infrastructure asset performance derived from either a frequentist or Bayesian approach, investors should be mindful of the impact from potential data limitations and Bayesian prior assumptions on the reliability of estimates. It is crucial for investors to account for these inherent methodological caveats when drawing conclusions.**

Summary

We develop and estimate a model of infrastructure equity income returns and price returns using the infrastructure asset-level dataset. The model involves two "transition matrices" that describe an asset's income return behavior *every period*, based on the asset's income return behavior in the *preceding period*. The first transition matrix (Step 1) determines *if* an asset will pay income in the current period whereas the second transition matrix (Step 2) determines the *magnitude* of the asset's income return for that period.

We examine in detail two approaches to estimate these two transition matrices – Bayesian and frequentist – and compare their key differences in interpreting final estimation. One main advantage of the Bayesian approach is its ability to incorporate prior knowledge. When data are limited, the Bayesian approach provides a way to integrate prior knowledge with available evidence whereas the frequentist approach might struggle to produce reliable estimates due to insufficient sample size. On the other hand, the frequentist approach relies exclusively on data for inference, avoiding the potential subjectivity introduced by Bayesian priors.

References

Blanc-Brude, F., M. Hasan., T. Whittaker. (2016) "Revenue and Dividend Payouts in Privately-held Infrastructure Investments. Evidence from 15 Years of UK Data". EDHEC*infra.*

BCG. (2024). "Global Asset Management Report 2024: AI and the Next Wave of Transformation."

Chen, A. and J. Shen. (2025). "Breaking Down Direct Infrastructure: Performance, Return Attribution, & Inflation Resilience." PGIM Multi-Asset Solutions.

Fornacon-Wood, I., H. Mistry., C. Johnson-Hart, C. Faivre-Finn, J. O'Connor and G. Price. (2021). "Understanding the Differences Between Bayesian and Frequentist Statistics". DOI: *https//doi.org/10.1016/j.ijrobp.2021.12.011*.

Preqin. (2024). "Preqin Global Report 2024: Infrastructure."

Shen, J. and F. Blanc-Brude. (2022). "Direct Infrastructure Equity: Performance, Cash Flows & Portfolio Allocation." PGIM and EDHEC*infra.*

Appendix

A1. *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.

A2. *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.

Appendix B

An Example of Estimating Zero *vs.* Non-zero Income Return State Transition Matrix using Frequentist Approach (MLE)

We use a binomial likelihood function to estimate the transition probability of a brownfield asset with a Non-zero income return state in the prior year as there are only two possible outcomes (transitioning from Non-zero to Zero and staying in Non-zero). The binomial likelihood for a single transition probability (π) is

$$L(\pi; k, n) = \binom{n}{k}\pi^{k}(1-\pi)^{n-k}$$

n is the total number of trials
k is the number of transitioning from Non-zero to Zero income return State
π is the probability of the transition from Non-zero to Zero income return State (to be estimated)

For example, for the brownfield asset (11-20y), k = 78 and n = (1,772+78) = 1,850.

To estimate π with Maximum Likelihood (MLE), we take the natural logarithm of the likelihood function (ignoring coefficients $\binom{n}{k}$ to get:

$$\log\big(L(\pi)\big) = klog(\pi) + (n-k)\log(1-\pi)$$

To maximize the log-likelihood, we take the derivative with respect to p, set to zero and solve for π:

$$\frac{\partial logL}{\partial \pi} = \frac{k}{\pi} - \frac{n-k}{1-\pi} = 0$$

$$\pi = \frac{k}{n}$$

In the case of a brownfield asset with a Non-zero income return state in the prior year, the transition probability from Non-zero to Zero income return state is therefore 78/1,850 = 4.2%. The probability of staying in Non-zero income return state is 1- π = 1-4.2% = 95.8%.

Appendix C

An Example of Estimating Zero *vs.* Non-zero Income Return State Transition Matrix using Bayesian Estimation

Suppose we want to estimate the probability (π) of an asset the transition from Non-zero to Zero income return State using Bayesian Estimation. Like the frequentist approach, it has the following binomial likelihood function:

$$L(\pi; k, N) = f(k, n|\pi) = \binom{n}{k} \pi^k (1-\pi)^{n-k}$$

Suppose π has a beta prior $f(\pi) = beta(\alpha, \beta) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \pi^{\alpha-1}(1-\pi)^{\beta-1}$, with mean $\frac{\alpha}{\alpha+\beta}$.

According to the Bayes Rule, the posterior becomes:

$$f(\pi|k,n) = \frac{f(k,n|\pi)\, f(\pi)}{\int f(k,n|\pi)\, f(\pi) d\pi}$$

$$\propto \frac{\pi^k(1-\pi)^{n-k}\, \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \pi^{\alpha-1}(1-\pi)^{\beta-1}}{\int_0^1 \pi^y (1-\pi)^{n-k} \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \pi^{\alpha-1}(1-\pi)^{\beta-1} d\pi}$$

$$\propto \frac{\pi^{\alpha+k-1}(1-\pi)^{\beta+n-k-1}}{\frac{\Gamma(\alpha+y)\Gamma(\beta+n-k)}{\Gamma(\alpha+\beta+n)} \int_0^1 \frac{\Gamma(\alpha+\beta+n)}{\Gamma(\alpha+k)\Gamma(\beta+n-k)} \pi^{\alpha+k-1}(1-\pi)^{\beta+n-k-1}\, d\pi}$$

$$\propto \frac{\Gamma(\alpha+\beta+n)}{\Gamma(\alpha+k)\Gamma(\beta+n-k)} \pi^{\alpha+k-1}(1-\pi)^{\beta+n-k-1}$$

$$\pi|k,n \sim Beta(\alpha+k, \beta+n-k)$$

with mean of $\frac{\alpha+k}{\alpha+\beta+n}$.

Note the posterior mean can be broken down to:

$$\frac{\alpha+k}{\alpha+\beta+n} = \frac{\alpha+\beta}{\alpha+\beta+n} \cdot \frac{\alpha}{\alpha+\beta} + \frac{n}{\alpha+\beta+n} \cdot \frac{k}{n}$$

$$\frac{\alpha+\beta}{\alpha+\beta+n} : Prior\ weight$$

$$\frac{\alpha}{\alpha+\beta} : Prior\ mean$$

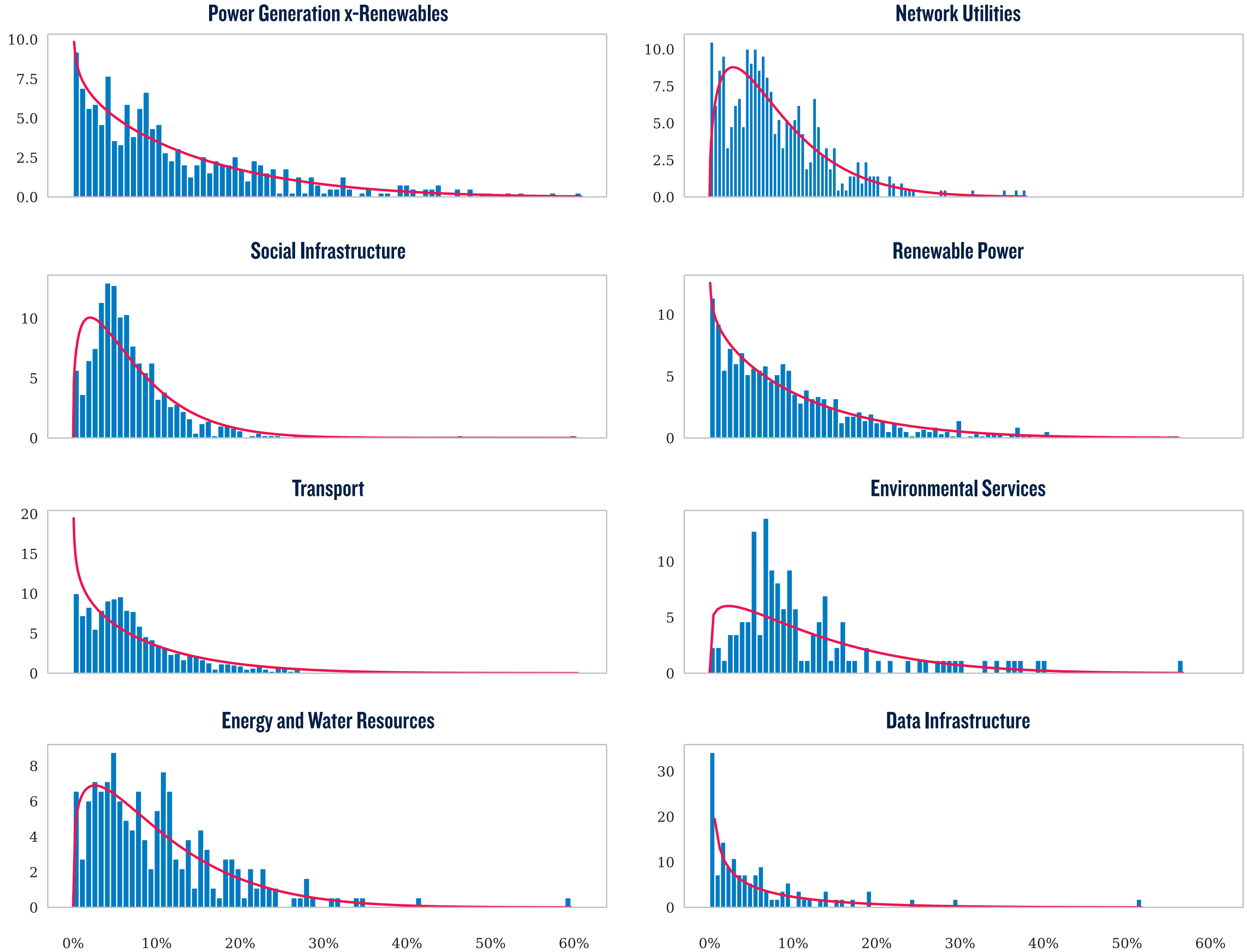
$$\frac{n}{\alpha+\beta+n} : Data\ weight$$

$$\frac{k}{n} : Data\ Mean$$

In other words, Posterior mean = Prior Mean × Prior weight + Data Weight × Data Mean. $\alpha+\beta$ gives an idea of how much data you would need to make sure that the prior doesn't have much influence on posterior.

Appendix D1

Non-zero Income Return Distributions (By Sector) and Fitted Beta Distribution



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

Appendix D2

Infrastructure Asset Income Returns, by Sector – Beta Distribution Parameter Calibration

	Power Generation x-Renewables	Environmental Services	Social Infrastructure	Energy and Water Resources	Data Infra	Transport	Renewable Power	Network Utilities
α	0.90	1.18	1.35	1.27	0.48	0.83	0.91	1.46
β	6.44	8.76	17.84	11.20	7.76	9.42	8.41	16.92

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

Appendix E

Annual Income Return Quartile (in a Non-Zero State) Transition Matrix – Bayesian Prior, Mean and Standard Deviation

Beta Mean				
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	60%	25%	12%	3%
Q3	22%	50%	18%	10%
Q2	12%	20%	50%	18%
Q1 - Bottom	9%	13%	18%	60%

Beta Standard Deviation				
	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	5%	5%	5%	5%
Q3	5%	5%	5%	5%
Q2	5%	5%	5%	5%
Q1 - Bottom	5%	5%	5%	5%

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

Annual Income Return Quartile (in a Non-Zero State) Transition Matrix, by Sector – Estimated with Bayesian Approach

	Power Generation x-Renewables				Social Infrastructure				Transport			
	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	59%	25%	10%	5%	66%	20%	9%	4%	65%	24%	6%	5%
Q3	22%	50%	24%	4%	21%	45%	24%	9%	19%	48%	25%	8%
Q2	11%	21%	50%	17%	8%	23%	48%	21%	11%	22%	52%	15%
Q1 - Bottom	9%	10%	15%	66%	5%	12%	18%	65%	7%	8%	16%	69%

	Environmental Services				Renewable Power				Network Utilities			
	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	59%	25%	11%	5%	60%	25%	13%	3%	55%	28%	11%	5%
Q3	20%	50%	21%	9%	24%	51%	19%	6%	23%	43%	27%	7%
Q2	15%	20%	48%	17%	9%	20%	50%	20%	8%	23%	49%	20%
Q1 - Bottom	8%	15%	20%	58%	8%	6%	15%	70%	11%	9%	15%	65%

	Energy and Water Resources				Data Infrastructure			
	Q4 - Top	Q3	Q2	Q1 - Bottom	Q4 - Top	Q3	Q2	Q1 - Bottom
Q4 - Top	61%	24%	9%	6%	61%	24%	9%	6%
Q3	20%	50%	22%	9%	20%	50%	22%	9%
Q2	9%	22%	49%	21%	9%	22%	49%	21%
Q1 - Bottom	11%	10%	19%	60%	11%	10%	19%	60%

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

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