INSTITUTIONAL ADVISORY & SOLUTIONS

MODELING PRIVATE INVESTMENT CASH FLOWS WITH MARKET-SENSITIVE PERIODIC GROWTH

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Modeling the cash flows of private investments is an important challenge for institutional investors. While the Takahashi and Alexander (TA) model for private investment cash flows has stood the test of time, we suggest a small change in the model that makes it more amenable to be deployed in market simulation and scenario analysis.

We provide a comparison between the original and modified TA model using cash flow data from Burgiss and show that our change does not detract from the spirit of the TA model but ties it with the public market in an intuitive way. We also provide a regression-based analysis to correlate the growth of public and private markets.

Modeling the cash flows of private investments is an important challenge for institutional investors. With a cash flow model an analyst can simulate possible market scenarios, cash flow shortfalls, and liquidity crises. Such analyses can be very useful for CIOs who make important decisions related to asset allocation and liquidity planning. A cash flow model is also useful to estimate the amount of dry powder which is a useful ingredient to design commitment strategies to build and maintain a desired private investment net asset value (NAV) in an overall multi-asset class portfolio.

We start with the Takahashi and Alexander (TA) model of private investment cash flows and explore a change to the model in which a series of periodic growth rates are used to model distributions and valuations (as opposed to a single lifetime growth parameter). In a simulation setting these growth rates can be correlated with public market returns which makes the model more realistic as the model's valuations and distributions become responsive to market movements. We also provide a regression-based framework to estimate period-specific growth.[1]

Using historical simulation on actual market data we show that the modified version of the TA model does a better job modeling actual cash flows, while retaining the spirit of the original TA model.

1 We do not change the contribution model as it is more involved and requires more granular data (see O'Shea and Jeet (2018a, 2018b)).

The findings shown are derived from statistical models. Reasonable people may disagree about the appropriate model and assumptions. Models should not be relied upon to make predictions of actual future account performance. See additional disclosures.

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The Takahashi and Alexander Model

Takahashi and Alexander (2001) provide an intuitive framework to model private capital cash flows and valuation. The model makes use of several parameters that must be calibrated using real cash flow and valuation data. With carefully estimated parameters the model can effectively forecast expected cash flows and valuation for a diversified portfolio of commitments or a vintage. The TA model is a continuous model; it does not incorporate the lumpiness of cash flows. More specifcally, it does not predict zeros (periods of inactivity) which are fairly common for individual funds. However, this is not an issue at the portfolio or vintage level in which cash flows are aggregated across funds. Below, we briefly describe the TA framework.

Contribution Model

The contribution model states that the capital call (C_t) amount in the next period is proportional to the uncalled capital (UC_{t-1}) amount at the end of current period. That is:

$$C_t = UC_{t-1} \times RC(Age_{t-1}),$$

where RC is the rate of contribution and Age_{t-1} is the age of investment at the end of current period. RC can be estimated in a straightforward manner using linear regression between observed time series of capital calls and uncalled capital.[2]

Distribution Model

The distribution model, similar to the contribution model, states that the distribution amount (D_t) in the next period is proportional to the NAV at the end of current period:

$$D_t = NAV_{t-1} \times (1+G) \times RD(Age_{t-1}, \text{bow}, L),$$

where RD specifies the rate of distribution. RD is further modeled as a function of age along with two constant parameters: bow and lifespan. The lifespan parameter L is the expected lifespan of a private investment, from the first call to the last distribution. The bow parameter lets users express their view on how the rate of distribution changes over the lifetime. A higher bow parameter produces a higher rate of distribution later in the investment's lifetime, implying that the investment has a longer duration as capital stays invested longer. The rate of distribution (RD) is defined as:

$$RD = \left(\frac{Age_{t-1}}{L}\right)^{\text{bow}}$$

A third parameter G specifies the rate at which NAV grows. Unlike the RC parameter, all the parameters (bow, growth and lifespan) in the distribution model are constants as they do not change with the age of the investment.

NAV Model

The NAV model assumes that all cash flows occur at the end of a period. Given the contribution and distribution models it is straightforward to model NAV:

$$NAV_t = NAV_{t-1}\,(1+G) + C_t - D_t$$

The NAV model is a direct consequence of the modified-Dietz return formula:

$$r_t^{\text{modDietz}} = \frac{NAV_t - NAV_{t-1} - CF}{NAV_{t-1} + WCF}$$

Since all cash flows happen at the end of a period, the time-weighted cash-flow term (WCF) is zero. This results in the following simplification:

$$r_t^{\text{modDietz}} = \frac{NAV_t - NAV_{t-1} - CF}{NAV_{t-1}}$$

$$NAV_t = NAV_{t-1}\,(1 + r_t^{\text{modDietz}}) - CF$$

Now replacing r_t^{modDietz} with a constant growth parameter G (a simplification) and CF with D_t-C_t, we get the TA NAV model.

2 RC is usually estimated as a piece-wise constant function of age.

TA Model Parameters

The parameters of the TA model are classified into two categories: model-specific and model-free. The RC and bow are the model-specific parameters, meaning they do not have a meaningful interpretation outside the model and must be estimated using the model equations. The growth and lifespan parameters are model-free (*i.e.*, exogenous to the model) and are meaningful numbers on their own and must be estimated independently of the TA model.

The TA model is an abstract model and its explanatory power lies in its parameter estimates. Commercial data providers provide parameter estimates and update them as new data become available. RC, growth, bow, and even lifespan parameters are continuously changing – as investors try to improve the TA model's ability to match actual cash flows and NAVs.

An Example

Figure 1 shows how the TA model generates cash flows and valuations given a set of parameters values. For a $1 commitment and assuming the rate of contribution (RC) to be 25% in the first year, 33% in the second year and 50% thereafter, the entire commitment is called by year 7 to 8. Assuming a lifespan of 13y, bow of 2 and growth (G) of 12%/y, all distributions are paid by the end of year 13 resulting in an annualized IRR of 12%.

Figure 2 plots the time series of uncalled capital, valuation and distribution. The uncalled capital decays at a rate specified by the rate of contribution. The NAV rises initially and reaches a peak; thereafter distributions increase and NAV declines. By the end of year 13 all cash flow activity ceases as the commitment reaches the end of its lifespan.

Note that the IRR of cash flows generated by the TA model is exactly 12%/y. This is not a coincidence, but rather a defining feature of the model illustrating its internal consistency. The IRR produced by the TA model's cash flows is independent of the RC, L, and bow parameters and is solely a function of the growth (G) parameter.

We compute several performance measures from the TA model cash flows (Figure 3). The money multiple (TVPI, a ratio of total value to paid in capital) of the investment is 1.73 which is a joint function of the *growth* and *bow* parameters. The endurance of IRR (or duration), which measures how long the full capital commitment stays invested, is about 4.5y over the investment's 13y lifetime.[3] Given the hypothetical performance of the assumed public market benchmark in the third column one can also compute the Kaplan-Schoar public market equivalent (PME) and direct alpha which is roughly the PME annualized over the investment duration.

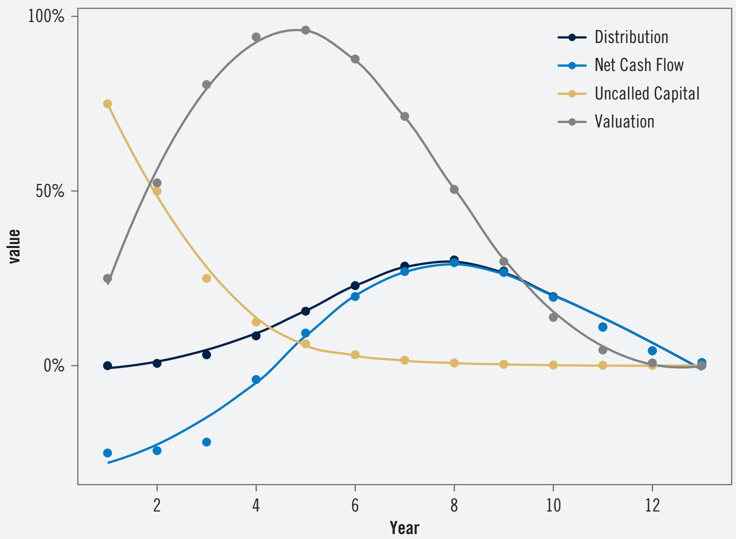
Figure 1: Illustration of TA Model: Parameters, Cash Flow, and Valuation

Year	Input		Parameters				Output				
	Commitment	Market	RC	L	G	B	Contribution	Uncalled	Distribution	Valuation	NCF
1	1.0	5.0%	0.25	13	12%	2	0.25	0.75	0.00	0.25	-0.25
2	1.0	4.0%	0.33	13	12%	2	0.25	0.50	0.01	0.52	-0.24
3	1.0	6.0%	0.50	13	12%	2	0.25	0.25	0.03	0.80	-0.22
4	1.0	1.0%	0.50	13	12%	2	0.13	0.13	0.09	0.94	-0.04
5	1.0	-1.0%	0.50	13	12%	2	0.06	0.06	0.16	0.96	0.09
6	1.0	2.0%	0.50	13	12%	2	0.03	0.03	0.23	0.88	0.20
7	1.0	7.0%	0.50	13	12%	2	0.02	0.02	0.29	0.71	0.27
8	1.0	8.0%	0.50	13	12%	2	0.01	0.01	0.30	0.50	0.29
9	1.0	2.0%	0.50	13	12%	2	0.00	0.00	0.27	0.30	0.27
10	1.0	5.0%	0.50	13	12%	2	0.00	0.00	0.20	0.14	0.20
11	1.0	7.0%	0.50	13	12%	2	0.00	0.00	0.11	0.04	0.11
12	1.0	2.0%	0.50	13	12%	2	0.00	0.00	0.04	0.01	0.04
13	1.0	3.0%	0.50	13	12%	2	0.00	0.00	0.01	0.00	0.01

Source: PGIM IAS. Provided for illustrative purposes only.

3 The endurance of IRR is computed as the log (IRR) / TVPI.

Figure 2: Visualization of TA Model Cash Flow and Valuation



Source: PGIM IAS. Provided for illustrative purposes only.

Figure 3: Performance Analysis of TA Model Cash Flows

Performance Measure	Value
TVPI	1.73
IRR	12.00%
Endurance	4.56
PME w.r.t Market	1.05
Direct Alpha	1.11%

Source: PGIM IAS. Provided for illustrative purposes only.

Periodic Growth TA Model

We explore a modified version of the TA model with potentially different values for the growth parameter in every period. The contribution model and the formula of RD remain unchanged.

Modified Distribution Model

$$D_t = NAV_{t-1} \times (1+G_{t-1}) \times RD(Age_{t-1}, \text{bow}, L),$$

Modified NAV Model

$$NAV_t = NAV_{t-1}\,(1+G_{t-1}) + C_t - D_t$$

The advantage of the modified model is that although the contribution model is unchanged, having the distribution and valuation models subject to growth specific to each period may bring the TA model closer to reality.

Estimating Periodic Growth with Lagged Regression

Periodic returns of private investments (*i.e.*, modified-Dietz returns or quarterly IRRs) are known to be smoothed (Getmansky, *et al.* 2004). To estimate these parameters using periodic returns we use a lagged regression model, along the lines of the CAPM.[4] Reliable estimates of these parameters can be useful for risk estimation, return attribution and asset allocation. We seek to model the periodic growth parameters, as a function of public market returns, to be able to simulate quarterly IRRs based on simulated market returns. Consider the following model:

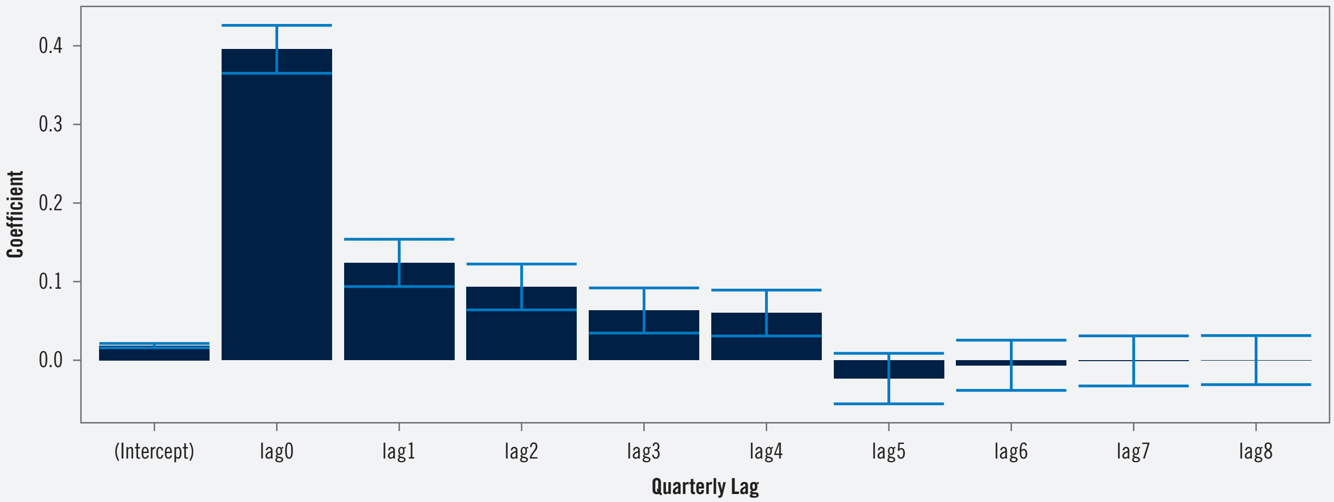
$$r_t^{\text{pvt}} - r_t^{\text{rf}} = \alpha + \beta\,(r_t^{\text{mkt}} - r_t^{\text{rf}}) + \epsilon,$$

in which the periodic returns of a private asset are regressed against periodic public market returns. The model decomposes the private asset's returns into three components: an alpha (a constant return), a beta (a return correlated with the market excess return), and an unexplained, or idiosyncratic, return that has a mean of zero and is uncorrelated with the market excess return.

Given that private returns are likely smoothed over time, to explain private returns in terms of the public market return we will use as explanatory variables the contemporaneous market return as well as several lagged market returns.[5] A model that includes K lags of market returns, in addition to the contemporaneous return, is as follows:

$$r_t^{\text{pvt}} = \alpha + \sum_{k=0}^{K} \beta_k r_{t-k}^{\text{mkt}} + \epsilon$$

Figure 4: Regression of Quarterly US Buyout Returns on Current and Lagged S&P 500 Returns



Note: The blue bars represent one standard error above and below the coefficient estimate.

Source: S&P, Burgiss, PGIM IAS. Provided for illustrative purposes only.

Figure 4 shows the coefficient estimates for US buyout quarterly returns, pooled across all vintages, from Q1 1980 to Q1 2020.[6] Up to 4 lags of S&P 500 quarterly returns seems relevant. The overall beta (*i.e.*, the sum of the coefficients on the contemporaneous and first four lagged public market returns) is about 0.75. The adjusted-R^2 is 0.58 and the standard deviation of residuals is about 1%. The regression was fitted using exponentially-smoothed weights on time-series observations (older observations are given smaller weights). We used a half-life of 20q, which means that a 5y-old observation is given only half the weight compared to the most recent observation.

4 See O'Shea and Jeet (2017) for a detailed literature review.

5 For simplicity, the term corresponding to risk-free rate is dropped here.

6 See coefficient estimates and fit statistics in the Appendix.

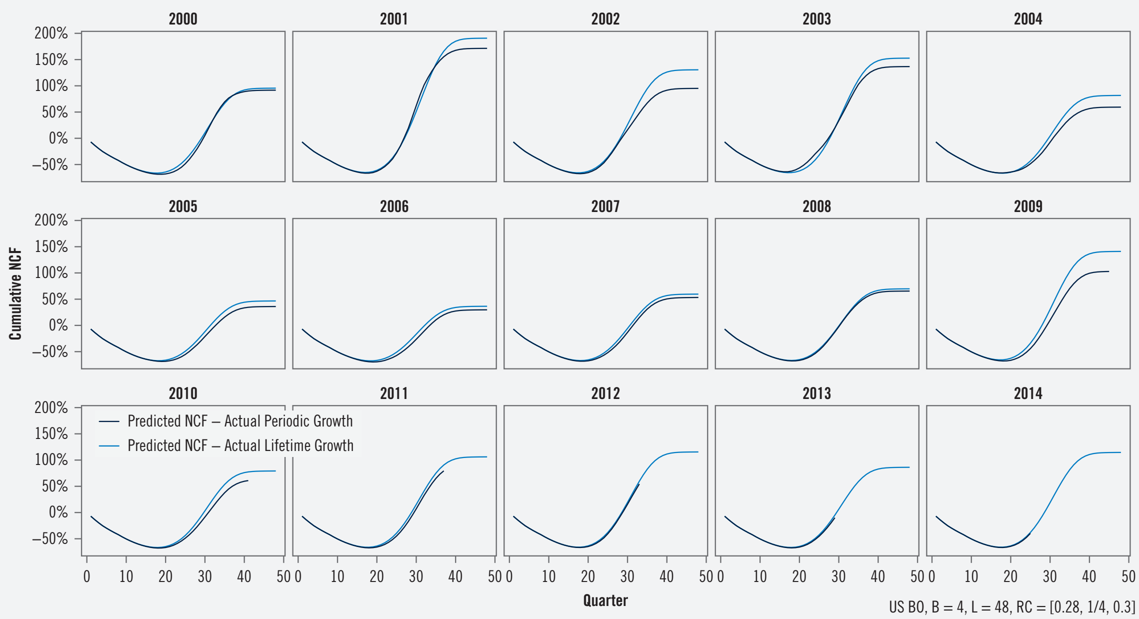
Comparison of Lifetime and Periodic Growth TA Models

We now compare the two versions of the TA model: one that uses a single lifetime growth parameter and one that uses a set of periodic growth parameters. For this comparison we fix all other TA parameters which we calibrate using pooled US buyout data across vintages 1980 through 2020. We use a bow factor of 4, lifespan of 12y, and rate of contribution 28% in the first year, 25% in the second year and 30% onwards.

To begin, we first use actual growth data for the two sets of growth parameters. For the lifetime growth parameter, we use the actual 12y IRR, when available, and since-inception IRR otherwise, as reported by Burgiss. For the set of periodic growth parameters, we use actual quarterly IRRs, also from Burgiss. This exercise provides an "estimation-free" comparison between the two models. In reality, the value of a cash flow model lies in its predictive power for which we would also have to predict (or, estimate) the growth parameter.

We compare these two TA model versions using 15 consecutive vintages from 2000 to 2014. Figure 5 shows the cumulative net cash flow, by vintage, generated by each model. A quick look at Figure 5 may tempt one to conclude that the two models are nearly the same, as the periodic and lifetime growth models' cumulative cash flows track each other well. Toward the end of 12y lifespan the periodic and lifetime models start to drift apart as the quarterly IRRs become noisier as valuations gets smaller. However, since these noisy periodic growth estimates are applied to smaller valuations, the gap between the two models is effectively small.

Figure 5: Comparison of TA Model Versions – Actual Lifetime vs. Actual Periodic Growth Data
Estimated Cumulative Net Cash Flow, by Vintage



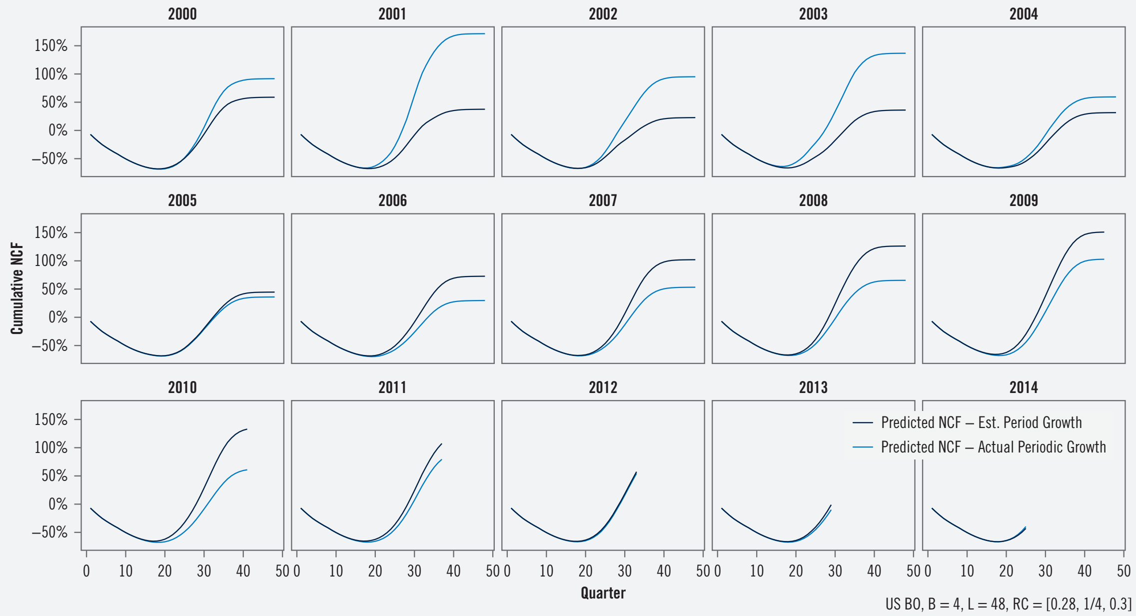
Source: S&P, Burgiss, PGIM IAS. Provided for illustrative purposes only.

Having established that the periodic growth TA model version can potentially perform as well as the lifetime growth version, the issue becomes how well can we estimate periodic growth. Figure 6 compares two periodic growth TA models: One using *actual* periodic growth data (Figure 5) and one using *estimated* periodic growth data from the lagged regression as described above. We ran the lagged regression every quarter using data only available up to, but not including, the current quarter. Using the regression coefficient estimates and actual market returns, we estimate the quarterly IRRs and use them as the periodic growth parameters.[7] The estimated quarterly IRRs are independent of underlying NAV size and cash flows.

As expected, Figure 6 shows that the actual and estimated quarterly IRRs produce different cumulative cash flows for a given vintage. However, for most vintages, they follow each other reasonably well. But the real test is how well the predicted net cash flows compare with actual net cash flows.

7 In reality we will also have to predict market return for the most recent quarter, which is a separate challenge. We are using actual S&P 500 index returns because we are interested in the ability of the TA model using the best possible estimates of the periodic growth parameters.

Figure 6: Comparison of TA Model Versions – Actual vs. Estimated Periodic Growth Parameters
Estimated Cumulative Net Cash Flows, by Vintage



Source: S&P, Burgiss, PGIM IAS. Provided for illustrative purposes only.

Figure 7: Performance of TA Model Version Using Estimated Periodic Growth
Cumulative Net Cash Flows: Model vs. Actual, by Vintage

Source: S&P, Burgiss, PGIM IAS. Provided for illustrative purposes only.

Figure 7 compares the model cumulative net cash flows using regression-based periodic growth estimates with actual vintage-level cumulative net cash flows, from Burgiss (scaled to match a dollar of commitment for each vintage). It is evident from Figure 7 that the TA framework with out-of-sample estimated periodic-specific growth rates does a reasonably good job matching actual net cash flows. The large difference from vintage 2006 onward (in the latter half of lifespan) could be due to multiple factors including modeling limitations, a change (due to the financial crisis of 2008) in the bow factor, lifespan, or even RC parameters. How good is the TA model to match actual net cash flows? This is an interesting but a separate topic beyond the scope of this paper. The purpose of this paper is by and large served by Figures 5 and 6 in which we show that, given the TA model, changing the lifetime growth to period-specific growth does not alter the model significantly but makes it easy to be deployed in simulation settings to generate market-sensitive cash flows.

Conclusion

The Takahashi and Alexander's framework to model private capital portfolio's cash flows has stood the test of time. However, estimating lifetime growth parameter remains a challenge, especially in a simulation setting in which market returns are sampled many times. How a private investment might behave in different market scenarios is an important portfolio management question.

We present a modified version of the TA model in which the model's lifetime growth parameter is replaced with period-specific growth parameters – *i.e.*, a growth parameter for each period. Periodic growth values are modeled using lagged regression. The modified TA model provides a systematic way to link private capital growth and distribution patterns to the public markets. We present computational evidence using buyout and public market data to show the effectiveness of our approach to make the TA model more useful.

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Appendix

Figure A1: Regression Table of Figure 4: Coefficient Estimates

Coefficients	Estimate	Std. Error	t-statistic	p-value	Significance
Intercept	0.018567	0.002787	6.661	5.17E-10	***
Lag 0	0.395559	0.03047	12.982	2.00E-16	***
Lag 1	0.123824	0.030092	4.115	6.45E-05	***
Lag 2	0.09322	0.029165	3.196	0.00171	**
Lag 3	0.063234	0.028738	2.2	0.02935	*
Lag 4	0.060042	0.029194	2.057	0.0415	*
Lag 5	-0.02337	0.032121	-0.727	0.46814	
Lag 6	-0.00642	0.031941	-0.201	0.84102	
Lag 7	-0.00089	0.031851	-0.028	0.97786	
Lag 8	0.0001702	0.0312004	0.005	0.99566	

Source: S&P, Burgiss, PGIM IAS. Provided for illustrative purposes only.

Figure A2: Regression Table of Figure 4: Quality of Fit

Statistic	Value
Residual standard error	0.01081
Multiple R^2	0.5779
Adjusted R^2	0.5519
F-statistic, DF = (9, 146)	22.21
p-value	2.2e-16

Source: S&P, Burgiss, PGIM IAS. Provided for illustrative purposes only.

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