

Lucky Beta: The Timing Wedge and Capital Misallocation in Private Equity

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Abstract

The Public Market Equivalent (PME) is the ubiquitous benchmark for private equity performance. We demonstrate that standard PME embeds a structurally flawed asset-pricing assumption: it discounts private market cash flows as if they possess unit exposure ($\beta = 1$) to public equities. Recasting PME within a stochastic discount factor framework, we show that the valuation distortion induced by this constraint is driven by a first-order sufficient statistic: the interaction between a fund's excess market risk and its cash flow timing wedge. Applying a generalized estimator to a large sample of private funds, we find that the benchmark-implied one-factor exposure parameter exceeds 1 under the maintained zero-alpha pricing restriction for both buyout and venture capital, with bootstrap uncertainty reported in the main results. Because managers systematically distribute capital during procyclical market peaks, standard PME fails to adequately penalize these boom-time cash flows, synthesizing alpha out of levered market exposure. Using quartiles defined within strategy, we find economically meaningful ranking instability: nearly 26% of buyout funds and 11% of venture funds, shift performance quartiles, including the demotion of 18% of ostensibly top-quartile buyout funds (8% of venture respectively). Ultimately, standard PME acts as a misspecified pricing kernel that systematically rewards unpriced risk, creating an adverse selection problem for institutional investors.

Keywords: private equity; public market equivalent; asset pricing; cash-flow timing

JEL Classification: G12, G23, G24

1 Introduction

Private equity (PE) has become a core allocation for institutional portfolios, yet its performance measurement still relies on tools that were designed for, and behave well in, liquid public markets. In practice, Limited Partners (LPs) and researchers continue to report Internal Rate of Return (IRR), Total Value to Paid-In capital (TVPI), and, most prominently, Public Market Equivalents (PMEs) to compare irregular fund cash flows to a public benchmark. The appeal is obvious: PME is simple to compute and speak directly to the policy question, “did this fund beat public markets?” But the stakes have risen sharply as private markets have grown and distributions have become more cyclical and constrained. These features have been emphasized in recent empirical work documenting the pronounced procyclicality of private-market cash flow dynamics and exit environments (Axelson et al., 2013; Brown et al., 2021).

A large stream of academic literature has demonstrated that private equity performance measurement is fragile to data limitations (stale or strategic NAVs, reporting selection) and to the economic risks embedded in illiquid cash flows. Early evidence highlighted systematic overstatement and selection issues in reported performance (Phalippou and Gottschalg, 2009), while subsequent work showed that liquidity risk and cash-flow timing are central to understanding PE returns and investor experience (Franzoni et al., 2012; Robinson and Sensoy, 2016; Korteweg and Nagel, 2016). More recent research estimates returns directly from LP cash flows and documents cyclical risk that differs across fund types, underscoring that the risk adjustment problem is not a second-order detail but rather part of the fundamental object we are trying to measure (Ang et al., 2018; Gupta and Van Nieuwerburgh, 2021). The broader survey literature synthesizes these methodological challenges, highlighting that different empirical approaches can imply meaningfully different conclusions about risk-adjusted performance (Brown et al., 2025).

Against this backdrop, PME occupies a special place: it is widely used because it avoids some well-known pathologies of IRR and TVPI, mapping naturally into a public-market comparison (Kaplan and Schoar, 2005). Importantly, PME has also received theoretical foundations under specific preference and wealth assumptions (e.g., log utility and benchmark-as-wealth portfolio, Sorensen and Jagannathan (2015)), and related work interprets PME through a dynamic CAPM lens. At the same time, newer benchmarking proposals, such as Direct Alpha (Gredil et al., 2023) and Net Asset Value nowcasting (Brown et al., 2022), explicitly emphasize the need for economically well-founded public-market comparisons that can be used in portfolio problems, reflecting ongoing dissatisfaction with existing measures even among proponents of public benchmarking.

This paper identifies a critical gap that remains unresolved despite these advances: standard PME embeds an implicit pricing-kernel restriction that is rarely made explicit and, consequently, rarely stress-tested in a way that cleanly separates risk misspecification from cash-flow timing. In standard implementations, PME values all fund cash flows in units of the benchmark index, equivalently imposing a restricted stochastic discount factor that treats the fund’s cash flows as if they should be discounted like a claim with unit exposure to the benchmark ($\beta = 1$). Yet modern cash-flow-based asset-pricing

methods show that private equity risk exposures are heterogeneous across strategies and often exceed those of public equities (Phalippou, 2020; Ghysels et al., 2025). Existing approaches focus on average abnormal performance, but do not provide a transparent decomposition of how the $\beta = 1$ restriction interacts with the timing of calls and distributions to distort PME levels and rankings in large samples.

The contribution of this paper is to show that standard PME embeds a restrictive benchmark assumption that is typically left implicit: it prices private fund cash flows as if their market exposure were equal to one. Once fund cash flows are procyclical, this restriction generates a predictable distortion in measured performance. The paper therefore contributes not by proposing a new all-purpose fund-level performance metric, but by identifying a tractable decomposition of mismeasurement arising from the interaction of non-unit systematic exposure and cash-flow timing. To do so, we recast PME within a stochastic discount factor framework and derive a closed-form characterization of its sensitivity to the beta restriction. First, we show formally that standard PME corresponds to valuation under a benchmark-numeraire pricing kernel and therefore imposes $\beta = 1$. Second, we generalize PME to $\text{PME}_i(\beta)$ and derive a sufficient-statistics representation showing that the sensitivity of $\log \text{PME}$ to β depends on the difference between the call-weighted and distribution-weighted exposure of fund cash flows to cumulative market excess returns. This decomposition isolates the two mechanical drivers of PME mismeasurement: (i) the deviation of a fund’s systematic exposure from unity, and (ii) the timing wedge in its cash flows. Third, using a comprehensive panel of more than 2,600 funds from 1984 to 2021 with quarterly cash flows, we estimate strategy-level exposures and find betas significantly above one. We then quantify the economic magnitude of the resulting distortion, showing that standard PME systematically overstates the performance of procyclical funds and materially reshapes cross-sectional fund rankings. We further assess uncertainty via fund-level bootstrap inference, examine out-of-sample holdout validation, and evaluate robustness across alternative fund-weighting schemes and vintage subsamples.

The remainder of the paper is organized as follows: *Section 2* reviews the related literature and develops our conceptual framework. *Section 3* outlines our methodology and *Section 4* describes the proprietary dataset. *Section 5* presents our empirical results, sequentially detailing our strategy-level risk estimates, quantifying the magnitude of the timing wedge bias, and demonstrating the material ranking distortion with potential allocation consequences induced by standard quartile rankings. *Section 6* contextualizes these findings within the broader asset-pricing literature, and *Section 7* concludes with a summary of the study’s economic implications.

2 Related Literature and Conceptual Framework

2.1 Why performance measurement in private markets is fundamentally hard

PE and venture capital (VC) pose distinct challenges for standard asset-pricing and performance evaluation. Cash flows are irregular, capital is drawn down through capital calls, payouts occur via lumpy distributions, and interim valuations are not transaction prices. Survey work emphasizes that these frictions impede direct application of return-based asset-pricing tools and motivate methods built on cash flows and modeled valuation dynamics (Korteweg, 2019; Metrick and Yasuda, 2010). A further challenge is that conclusions about PE performance are sensitive to data construction and benchmarking conventions. Influential work finds buyout outperformance relative to public markets for some samples and periods, while VC outcomes vary considerably across vintages (Harris et al., 2014; Robinson and Sensoy, 2016). Other papers argue that reported performance can be overstated due to selection and residual value treatment, particularly when interim valuations enter evaluation (Phalippou and Gottschalg, 2009). We organize the literature into four strands: (i) PME-type benchmarking measures, (ii) SDF-based generalizations and fund-level abnormal performance metrics, (iii) cash-flow-based estimation of risk exposures, and (iv) work on cash-flow cyclicalities, liquidity, valuation dynamics, and discount-rate risk.

2.2 Benchmarking private funds against public markets: PME-family measures and Direct Alpha

The PME family was developed to overcome limitations of IRR and multiples. A prominent benchmark is the Kaplan–Schoar PME, which compares the present value of distributions to calls when both are discounted by realized public market performance (Kaplan and Schoar, 2005). Related PME variants (e.g., Long–Nickels type constructions and PME+ adjustments) address practical issues such as constraints of the synthetic public portfolio and potential pathologies (Sorensen et al., 2014). More recently, Gredil et al. (2023) advocate the Direct Alpha method as an annualized excess return measure based on benchmark-discounted cash flows and argue that several PME approaches are heuristic when converted into annualized excess returns. Our focus is not to propose a new benchmark measure, but to isolate and quantify a specific restriction embedded in standard PME practice: the implicit assumption that private fund cash flows behave as if they have unit exposure to the chosen public benchmark. Accordingly, our analysis should be understood as a critique of one widely used benchmarking convention within a broader set of private-market performance measures, rather than as a claim that standard PME exhausts current empirical practice.

2.3 The asset-pricing foundation: PME as a restricted stochastic discount factor

PME admits a natural interpretation through stochastic discount factors (SDFs) and numeraires. Under this interpretation, PME corresponds to valuing fund cash flows using a kernel proportional to the inverse of the benchmark’s cumulative return, effectively treating the benchmark as numeraire (Sorensen et al., 2014). In a textbook CAPM setting, discounting depends on a cash flow’s systematic risk exposure and the market risk premium; standard PME does not include an explicit beta adjustment, which is equivalent to imposing a normalization consistent with $\beta = 1$. Korteweg and Nagel (2016) provide a leading asset-pricing treatment of this insight by adapting SDF valuation methods to VC performance evaluation and developing a generalized approach that permits risk adjustment beyond mechanical PME benchmarking. More recent work on fund-level performance measurement emphasizes that PME-type measures can be noisy at the individual fund level and proposes alternative alpha-based statistics that retain the same aggregate pricing implications as generalized PME while improving fund-level inference (Korteweg and Nagel, 2025). Our objective is different. We do not ask which fund-level abnormal-performance statistic is best behaved in general. Instead, we isolate a specific source of benchmark misspecification embedded in standard PME practice: the implicit assumption that private fund cash flows are priced as if their systematic exposure to the benchmark were equal to one.

2.4 Estimating risk and abnormal performance from cash flows rather than NAV returns

A central divide in the literature concerns whether to infer risk and performance from interim reported NAVs or from cash flows. Cash-flow-based methods are attractive because calls and distributions are hard payments, while interim valuations can be stale, smoothed, and influenced by reporting conventions. Driessen et al. (2012) develop a methodology to estimate abnormal performance and risk exposures of non-traded assets from a cross-section of cash flows. Ang et al. (2018) use an unbalanced panel of LP cash flows to infer an implicit time series of private equity returns and decompose returns into components spanned by traded factors versus a time-varying private equity premium. Related work suggests that a substantial share of private equity variation can be linked to public-market risk, although spanning is not complete and the mapping depends on the asset class, benchmark, and empirical design. Our paper adopts this literature’s cash-flow-based perspective, but with a narrower objective: rather than attempting to fully characterize all relevant sources of private-market risk, we quantify how much performance mismeasurement arises when standard PME imposes a unit-beta restriction on cash flows whose effective market exposure differs from one. This wedge is the central object of interest in our analysis.

2.5 Cash-flow cyclicalities, liquidity, and the economics of timing

PE investors’ experience is shaped by the timing of calls and distributions. [Robinson and Sensoy \(2016\)](#) show that public and private equity waves co-move and study implications for cash flows, performance measurement, and funding liquidity risk. Liquidity-based explanations are also developed in work linking PE performance to traded liquidity factors, with multi-factor adjustments substantially affecting inferred alphas ([Franzoni et al., 2012](#)). Theory clarifies how illiquidity and fee structures enter the investor’s certainty-equivalent valuation and distinguishes spanned from non-spanned risks ([Sorensen et al., 2014](#); [Metrick and Yasuda, 2010](#)).

2.6 NAV dynamics and discount-rate risk: what cash flows solve and what they do not

Even when the primary estimator uses cash flows, valuation dynamics matter for terminal values and for interpreting the broader literature. [Brown et al. \(2022\)](#) develop a state-space approach to infer unsmoothed NAVs and document economically meaningful heterogeneity in risk across funds and over time. A distinct channel is discount-rate variation. [Boyer et al. \(2023\)](#) use secondary-market transactions to show that discount rates vary considerably and argue that cash-flow measures can appear large even when standard CAPM alpha for a secondary-market index is near zero. Our analysis isolates the wedge arising from a beta restriction inside PME; it does not claim that this is the only relevant source of private-market performance mismeasurement. Rather, discount-rate variation, liquidity risk, and non-spanned components of private-market cash flows remain complementary mechanisms that may matter alongside the benchmark misspecification studied here. Accordingly, our one-factor beta adjustment should be interpreted as a parsimonious first-pass correction to the unit-beta restriction embedded in standard PME, rather than as a complete description of private-market risk. This simplification is likely most defensible for PE and VC funds, where broad public-equity exposure plausibly captures the dominant benchmarking dimension in a first-order comparison with public markets.

2.7 Summary and roadmap

Section 2 positions our contribution within four related strands of research. First, it reviews the PME family of public-market benchmarks and recent refinements that aim to improve fund-level inference. Second, it discusses asset-pricing interpretations of PME and generalized PME as restricted pricing kernels, clarifying the implicit $\beta = 1$ assumption that motivates our analysis. Third, it surveys cash-flow-based methods for estimating risk and return in illiquid assets and contrasts them with NAV- and return-based approaches that can be affected by valuation smoothing. Fourth, it summarizes evidence on the cyclicalities of calls and distributions and on liquidity, valuation, and discount-rate channels that can create wedges between cash-flow-based performance measures and standard factor-model alphas. This synthesis motivates the empirical design in *Section 3*. We estimate strategy-

level systematic exposure directly from cash flows using an SDF-based pricing-error framework and then quantify how much standard PME mismeasures fund performance when the imposed unit-beta restriction fails. The emphasis is therefore not on proposing a universal one-factor model of private-market risk, but on identifying and decomposing a tractable and economically meaningful source of benchmark misspecification.

3 Methodology

3.1 Data structure and cash-flow construction

We observe quarterly fund cash flows for funds $i = 1, \dots, N$ at quarter-end dates $q \in \{1, \dots, Q\}$ spanning 1984Q1–2021Q4. For each fund-quarter we observe capital calls $C_{i,q} \geq 0$, distributions $D_{i,q} \geq 0$, and end-of-quarter net asset values $NAV_{i,q} \geq 0$. Because our primary asset-pricing approach is cash-flow based, we treat interim NAVs as auxiliary inputs and use them only to construct a terminal value for non-liquidated funds. Let

$$T_i \equiv \max\{q : NAV_{i,q} \text{ is observed}\}. \quad (3.1)$$

We define terminal-adjusted distributions as

$$\tilde{D}_{i,q} \equiv \begin{cases} D_{i,q} + NAV_{i,T_i}, & q = T_i, \\ D_{i,q}, & q < T_i, \end{cases} \quad (3.2)$$

and net cash flow to the LP as

$$X_{i,q} \equiv \tilde{D}_{i,q} - C_{i,q}. \quad (3.3)$$

This convention makes liquidated and non-liquidated funds comparable within the sample window.

3.2 Benchmark index and risk-free series

Let I_q denote the quarter-end level of a total return benchmark index, normalized such that $I_0 = 1$. Quarterly gross market returns are computed from levels as

$$R_{m,q} \equiv \frac{I_q}{I_{q-1}}, \quad r_{m,q} \equiv \ln(R_{m,q}). \quad (3.4)$$

We observe monthly T-bill returns. Let the monthly gross risk-free return be $R_{f,m} = 1 + r_{f,m}$. The quarterly gross risk-free return is constructed by compounding the three months within quarter q :

$$R_{f,q} \equiv \prod_{k=1}^3 R_{f,m_k}, \quad r_{f,q} \equiv \ln(R_{f,q}). \quad (3.5)$$

All series are aligned to a quarter-end timing convention.

3.3 SDF framework and cash-flow pricing errors

Let m_q denote a one-quarter stochastic discount factor (SDF) increment and define the cumulative discount factor $M_q \equiv \prod_{\tau=1}^q m_\tau$. If fund cash flows are correctly priced under a candidate SDF family, the discounted value of the net cash flows should be close to zero on average.

To avoid non-positivity problems associated with linear SDFs and to connect to a log-linearized CAPM, we use an exponential-affine SDF indexed by market exposure β :

$$m_q(\beta) \equiv \frac{1}{R_{f,q}} \exp\left(-\beta(r_{m,q} - r_{f,q})\right). \quad (3.6)$$

This specification has clean limiting cases: (i) $\beta = 0$ implies discounting at the risk-free rate only, $m_q(0) = 1/R_{f,q}$; (ii) $\beta = 1$ implies market-numeraire discounting, $m_q(1) = 1/R_{m,q}$.

For any β , define the cumulative discount factor:

$$M_q(\beta) \equiv \prod_{\tau=1}^q m_\tau(\beta). \quad (3.7)$$

The fund-level pricing error under β is:

$$\Pi_i(\beta) \equiv \sum_{q=1}^{T_i} M_q(\beta) X_{i,q}. \quad (3.8)$$

A small $\Pi_i(\beta)$ indicates that the fund's realized cash flows are approximately correctly priced by the SDF indexed by β .

3.4 Strategy-level estimation of market exposure

Fund-level identification from a single realized cash-flow path can be noisy. Our baseline specification therefore estimates β at the strategy level $g \in \{\text{buyout, venture capital, pooling information across funds and aligning with economic heterogeneity across private market strategies}\}$. To avoid the trivial solution ($M_q \rightarrow 0$) inherent in zero-alpha SDF restrictions, and to prevent extreme fund-level outliers from dominating the estimator, we estimate β_g by minimizing the squared error of the strategy's weighted Generalized PME ratio.

For each strategy group g , we estimate:

$$\hat{\beta}_g \equiv \arg \min_{\beta \in \mathcal{B}} \left(\frac{\sum_{i \in g} w_i PV_{D,i}(\beta)}{\sum_{i \in g} w_i PV_{C,i}(\beta)} - 1 \right)^2 \quad (3.9)$$

where $PV_{D,i}(\beta)$ and $PV_{C,i}(\beta)$ are the present values of the fund's adjusted distributions and calls discounted by $M_q(\beta)$, and w_i are predetermined fund weights (baseline $w_i = 1$). Standard errors are

computed using a fund-level bootstrap that resamples funds with replacement within each strategy and re-estimates $\hat{\beta}_g$. Our baseline specification uses equal fund weights; alternative weighting schemes are reported as robustness checks.

3.5 Practical estimation: existence, uniqueness, and numerical implementation

A root-finding approach based on imposing $NPV_i(\beta) = 0$ for each fund need not yield a solution for every fund due to idiosyncratic cash-flow realizations, terminal NAV measurement error, or factor misspecification. The minimum-distance estimator in (3.9) avoids this problem by estimating β from squared pricing errors rather than requiring each fund to satisfy a zero-NPV restriction exactly.

Numerically, we compute $M_q(\beta)$ recursively:

$$M_q(\beta) = M_{q-1}(\beta) m_q(\beta), \quad M_0(\beta) = 1, \quad (3.10)$$

which is stable and fast in large panels. To guard against local minima, we implement a two-step search: (i) evaluate the objective in (3.9) on a coarse grid over $\mathcal{B}$; (ii) refine using a one-dimensional optimizer initialized at the best grid point. We report diagnostics on the curvature of the objective around $\hat{\beta}_g$ and verify robustness to alternative bounds and starting values. As an additional empirical check, we estimate strategy betas on a training subsample and evaluate pooled beta-adjusted PME on a holdout subsample.

3.6 Generalized PME and mismeasurement under the $\beta = 1$ restriction

To preserve comparability with the PME literature, we retain the [Kaplan and Schoar \(2005\)](#) ratio structure, but discount cash flows using the cumulative stochastic discount factor $M_q(\beta)$ introduced in [Section 3.3](#). Fund-level performance is therefore evaluated using the same pricing kernel that underlies the estimation of strategy-level betas:

$$\text{PME}_i(\beta) \equiv \frac{\sum_{q=1}^{T_i} \tilde{D}_{i,q} M_q(\beta)}{\sum_{q=1}^{T_i} C_{i,q} M_q(\beta)}. \quad (3.11)$$

When $\beta = 1$, $\text{PME}_i(1)$ is numerically equivalent to the standard PME, since any common scaling factor cancels between the numerator and denominator. We use $\text{PME}_i(\beta)$ not to claim a universally preferred fund-level performance measure, but to isolate the effect of relaxing the unit-beta restriction embedded in the standard PME benchmark.

Define $\alpha_i(\beta) \equiv \ln \text{PME}_i(\beta)$. Our measure of mismeasurement compares the conventional benchmark

that imposes $\beta = 1$ with the exposure-adjusted benchmark based on the estimated strategy beta $\hat{\beta}_{g(i)}$:

$$Bias_i \equiv \alpha_i(1) - \alpha_i(\hat{\beta}_{g(i)}). \quad (3.12)$$

A positive value of $Bias_i$ indicates that the standard PME overstates fund performance relative to the beta-adjusted benchmark. In addition, we study rank instability using Spearman rank correlations and transitions across performance quartiles.

3.7 Mechanism: sufficient-statistics decomposition via PME beta sensitivity

Let

$$PV_{D,i}(\beta) \equiv \sum_{q=1}^{T_i} \tilde{D}_{i,q} M_q(\beta), \quad PV_{C,i}(\beta) \equiv \sum_{q=1}^{T_i} C_{i,q} M_q(\beta),$$

so that $PME_i(\beta) = PV_{D,i}(\beta)/PV_{C,i}(\beta)$. The sensitivity of log PME with respect to β can then be written as

$$\frac{\partial \ln PME_i(\beta)}{\partial \beta} = \mathbb{E}_{i,\beta}^D[\partial_\beta \ln M_q(\beta)] - \mathbb{E}_{i,\beta}^C[\partial_\beta \ln M_q(\beta)], \quad (3.13)$$

where $\mathbb{E}_{i,\beta}^D[\cdot]$ and $\mathbb{E}_{i,\beta}^C[\cdot]$ denote weighted averages with weights proportional to discounted distributions and discounted calls, respectively. Under the exponential-affine pricing kernel, see *Equation (3.6)* and *Equation (3.7)*,

$$m_q(\beta) = R_{f,q}^{-1} \exp(-\beta(r_{m,q} - r_{f,q})), \quad M_q(\beta) = \prod_{\tau=1}^q m_\tau(\beta),$$

this implies

$$\partial_\beta \ln M_q(\beta) = -\sum_{\tau=1}^q (r_{m,\tau} - r_{f,\tau}).$$

Substituting into equation (3.13) yields

$$\frac{\partial \ln PME_i(\beta)}{\partial \beta} = \mathbb{E}_{i,\beta}^C \left[\sum_{\tau=1}^q (r_{m,\tau} - r_{f,\tau}) \right] - \mathbb{E}_{i,\beta}^D \left[\sum_{\tau=1}^q (r_{m,\tau} - r_{f,\tau}) \right]. \quad (3.14)$$

Evaluated at $\beta = 1$, this expression motivates the following timing wedge:

$$S_i \equiv \mathbb{E}_{i,1}^C \left[\sum_{\tau=1}^q (r_{m,\tau} - r_{f,\tau}) \right] - \mathbb{E}_{i,1}^D \left[\sum_{\tau=1}^q (r_{m,\tau} - r_{f,\tau}) \right]. \quad (3.15)$$

A first-order expansion around $\beta = 1$ then implies

$$Bias_i \approx -(\hat{\beta}_{g(i)} - 1) S_i. \quad (3.16)$$

Equation (3.16) decomposes performance mismeasurement into two components: (i) the extent to which a strategy’s systematic exposure differs from unity, and (ii) the extent to which the timing of a fund’s calls and distributions differentially loads on cumulative market excess returns, hence the cyclical nature of the fund’s cash-flow timing.

3.8 Implementation algorithm

Algorithm 1. Cash-flow SDF beta estimation and PME mismeasurement.

1. **Terminal NAV:** For each fund i , set T_i as the last quarter with observed $NAV_{i,q}$. Construct $\tilde{D}_{i,q}$ as in (3.2) and net cash flows $X_{i,q}$ as in (3.3).
2. **Quarterly returns:** Compute $R_{m,q} = I_q/I_{q-1}$ and $R_{f,q} = \prod_{k=1}^3 (1 + r_{f,m_k})$. Set $r_{m,q} = \ln R_{m,q}$ and $r_{f,q} = \ln R_{f,q}$.
3. **SDF and pricing errors:** For candidate β , compute $m_q(\beta)$ from (3.6) and $M_q(\beta)$ recursively using (3.10). Compute $\Pi_i(\beta)$ from (3.8).
4. **Estimate exposures:** For each strategy group g , estimate $\hat{\beta}_g$ by minimizing (3.9). Report bootstrap standard errors, local curvature diagnostics, holdout-sample validation, and robustness to alternative weighting schemes and vintage subsamples. We treat the in-sample pooled PME evaluated at $\hat{\beta}_g$ only as an implementation check.
5. **PME and mismeasurement:** Compute $PME_i(1)$ and $PME_i(\hat{\beta}_{g(i)})$ using (3.11). Compute $Bias_i$ via (3.12). Compute timing wedge S_i via (3.15) and evaluate the approximation (3.16).

4 Data collection

4.1 Raw Data and Sourcing

Our primary analysis utilizes a confidential, proprietary dataset obtained from one of the largest private equity fund-of-funds investment managers globally. The raw dataset encompasses 5,982 private capital funds raised by 2,511 unique General Partners (GPs), covering buyout, venture capital, private credit (including distressed), and real assets (including infrastructure, natural resources, and real estate). The dataset represents approximately \$4.6 trillion in committed capital.¹ Crucially, this dataset is compiled from a triangulation of several leading commercial databases, cross-referenced and complemented with proprietary data derived from the manager’s confidential due diligence processes and direct fund-of-funds investments. By leveraging this rigorously aggregated, multi-source dataset, we significantly mitigate the reporting, backfill, and survivorship biases observed when being reliant on a single commercial

¹Note that approximately 25% of the funds in the raw dataset do not report a formal fund size; hence, the actual committed capital captured in the aggregate cash flows is inherently larger.

database (Harris et al., 2014; Brown et al., 2025). The underlying data provides over 600,000 time-series observations of fund-level capital calls, distributions, and quarterly Net Asset Values (NAVs).

4.2 Sample Selection and Terminal NAV Treatment

To ensure the robustness of our cash-flow-based beta estimation, we apply several standard filtering criteria to arrive at our final analytical sample. We restrict the universe to funds with vintage years between 1984 and 2021. We exclude recent vintages (post-2021) because these funds remain in their early investment periods; their performance is predominantly driven by interim, smoothed NAVs rather than realized cash distributions, which would distort our terminal-cash-flow optimization (Brown et al., 2022). Furthermore, we exclude funds lacking clear strategy classifications or possessing insufficient cash flow histories (fewer than 4 distinct cash flow events). Following these filters, our final cross-sectional sample consists of 2,646 buyout and venture funds. For these funds, the final reported NAV at the end of our sample period (Q4 2021) is treated as a terminal liquidating distribution, consistent with standard PME literature (Kaplan and Schoar, 2005).

4.3 Benchmark Selection

To evaluate the PME and extract the implicit market risk parameters (β), we require a representative public equity benchmark. We use the Russell 3000 Total Return Index as our preferred baseline benchmark because it captures a broader cross-section of the U.S. equity market than the S&P 500². By capturing approximately 98% of the investable U.S. equity market, the Russell 3000 explicitly incorporates the mid-cap and small-cap risk premiums that are fundamentally characteristic of middle-market buyout targets and late-stage VC (Harris et al., 2014; Gupta and Van Nieuwerburgh, 2021). Utilizing a narrower, large-cap-dominated index like the S&P 500 would artificially inflate our estimated private market betas by failing to account for the size factor (*SMB*) inherently embedded in private equity portfolios. Consequently, the Russell 3000 Total Return Index ensures that our strategy-level beta estimates reflect true systematic market exposure rather than a simple size mismatch.

5 Findings

5.1 Strategy-Level Risk Estimates and Estimation Diagnostics

To evaluate the risk-adjusted performance of private market funds, we first estimate the aggregate market risk parameter, beta, for each primary investment strategy (buyout and venture capital). Using the Generalized PME Ratio estimator detailed in *Equation (3.11)*, we solve for the beta that equates

²Yet, we provide further robustness analysis. Here, *Table 2* in the appendix reports benchmark robustness using the S&P 500 Total Return Index.

the present value of aggregate strategy-level capital calls to the present value of aggregate distributions. We begin by estimating strategy-level exposure parameters for buyout and venture capital using the generalized PME ratio estimator in *Equation (3.9)*. Under the baseline equal-weight specification, the estimated beta is 1.65 for buyout and 1.30 for venture capital. *Table 1* reports these point estimates together with bootstrap standard errors, confidence intervals, and curvature diagnostics. In both strategies, the estimated exposure parameter significantly exceeds the unit-beta restriction embedded in standard PME, confirming that private market strategies inherently bear substantially higher systematic risk than the broader public equity market. *Table 1* also presents the strategy-level pooled PME ratios evaluated under both the standard industry assumption (PME_1) and our optimized risk parameter (PME_β). When evaluated using standard practice, the aggregate cash flows imply substantial historical outperformance, yielding a pooled PME_1 of 1.2291 for buyout and 1.1532 for venture capital.

Table 1: Strategy-Level Beta Estimates and Split-Sample Validation

	Buyout	Venture
No. Funds	1,096	1,550
Estimated $\hat{\beta}_g$	1.6487	1.2974
Bootstrap SE	0.0907	0.0637
95% CI	1.4797 - 1.8397	1.1744 - 1.4284
Curvature	0.1808	0.4400
No. holdout funds	554	777
Holdout pooled PME($\beta = 1$)	1.2291	1.1532
Holdout pooled PME($\hat{\beta}_g$)	0.9970	0.9891

Table 1 reports the baseline strategy-level beta estimates for buyout and venture funds using the Russell 3000 Total Return Index, together with bootstrap uncertainty, curvature diagnostics, and holdout-sample pooled PME validation.

However, when these identical aggregate cash flows are discounted using the strategy-specific stochastic discount factor derived from our estimated betas, the pooled PME_β for the respective strategy converges to 1. As expected from the estimation criterion, the pooled PME_β equals 1 by construction while the holdout pooled PME values deviate slightly; the informative objects are the estimated betas, their bootstrap uncertainty, and the fund-level ranking changes induced by replacing $\beta = 1$ with $\hat{\beta}_{g(i)}$. Economically, this suggests that the apparent aggregate alpha generated by these asset classes over our sample period is subsumed once correctly adjusted for the actual magnitude of market risk taken.

Table 2 in the appendix reports benchmark robustness using the S&P 500 Total Return Index. The table demonstrates that using the S&P 500 TR instead of the Russell 3000 TR yields qualitatively unchanged conclusions: estimated strategy-level betas remain significantly above one for both buyout and venture capital, and the holdout pooled PME evaluated at $\hat{\beta}_g$ remains close to one, confirming that the main findings are not driven by the choice of public-equity benchmark. *Table 3 in the appendix* shows that the main buyout and venture estimates remain qualitatively similar across equal-weight, call-weighted, and square-root-of-calls specifications, while *Table 4 in the appendix* further indicates that the main conclusion, namely exposure parameters above one, is preserved across vintage subsamples,

although magnitudes vary across market eras, particularly true for venture. Having established and validated these aggregate risk parameters, we next apply these empirically derived betas to evaluate the cross-sectional, fund-level performance distortions.

5.2 The Magnitude and Direction of the Bias: Visualizing the Timing Wedge

Having established that private market strategies exhibit systematic risk exposures in excess of the public equity benchmark, we next examine how this feature translates into fund-level performance mismeasurement. Consistent with *Equation (3.12)*, we define performance bias as the log difference between the conventional PME benchmark that imposes $\beta = 1$ and the exposure-adjusted benchmark:

$$Bias_i \equiv \ln PME_i(1) - \ln PME_i(\hat{\beta}_{g(i)}).$$

A positive value of $Bias_i$ therefore indicates that the standard PME overstates fund performance relative to the beta-adjusted measure. As shown in *Equation (3.16)*, this distortion admits a first-order sufficient-statistics representation:

$$Bias_i \approx -(\hat{\beta}_{g(i)} - 1) S_i,$$

where $\hat{\beta}_{g(i)} - 1$ captures the deviation of the strategy’s systematic exposure from unity and S_i captures the fund-specific timing wedge.

Figure 1 plots the realized bias, $\ln PME_i(1) - \ln PME_i(\hat{\beta}_{g(i)})$, against its first-order approximation, $-(\hat{\beta}_{g(i)} - 1)S_i$, separately for buyout (Panel A) and venture capital (Panel B). In both panels, the observations cluster tightly around the 45-degree line, indicating that the sufficient-statistics approximation captures most of the cross-sectional variation in mismeasurement (R^2 of 0.9962 and 0.9991 respectively). The distortion is therefore not idiosyncratic, but systematically related to the interaction between strategy-level market exposure and fund-level cash-flow timing. In the upper tail of the distribution, a mild convex deviation from the 45-degree line remains visible, consistent with higher-order terms omitted by the first-order expansion. This pattern is economically small and does not alter the central conclusion that the timing wedge provides a highly accurate summary statistic for the bias induced by imposing $\beta = 1$.

[Insert *Figure 1* about here]

Crucially, the empirical distribution in *Figure 1* indicates that realized bias is predominantly positive across the sample. Because our strategy-level estimates imply $\hat{\beta}_{g(i)} > 1$, this pattern in turn implies that the timing wedge S_i is predominantly negative. From *Equation (3.15)*, a negative timing wedge means that cumulative market excess returns are, on average, higher at the times when funds distribute capital than at the times when they call capital.

This pattern is consistent with two economic features of private market investing. First, over the

life of a typical fund, distributions tend to occur later than contributions and therefore mechanically coincide with states in which cumulative market returns are higher on average. Second, exit activity is procyclical: general partners are more likely to realize investments through IPOs or strategic sales when public market conditions are strong. Taken together, these features imply that standard PME, by imposing $\beta = 1$, does not apply a sufficiently strong discount to distributions that arrive in favorable aggregate states. The result is a systematic overstatement of risk-adjusted performance.

5.3 Cross-Sectional Implications for Capital Allocation

While the magnitude of the valuation bias demonstrates the theoretical flaw in standard benchmarking, the ultimate economic consequence of this distortion lies in capital allocation. Institutional investors (LPs) heavily rely on relative quartile rankings to identify top-tier managers, screen prospective investments, and allocate future capital. If the implicit $\beta = 1$ assumption of standard PME systematically overstates the performance of high-beta, procyclical funds, it follows that capital is being routinely misallocated across the private market universe.

To quantify this cross-sectional misallocation, we evaluate the quartile rank stability of the 2,646 funds in our sample. At a macro level, the overall rank correlation between the standard benchmark (PME_1) and our risk-adjusted framework (PME_β) appears highly stable, yielding a Spearman’s rho of 0.96. However, this aggregate correlation masks severe, localized rank turbulence at the quartile thresholds, the exact boundaries used by investors to make funding decisions. *Table 5 in the appendix* presents a transition matrix mapping funds from their standard PME_1 performance quartiles into their beta-adjusted quartiles under the estimated strategy-specific SDF.

[Insert *Table 5* about here]

The results reveal widespread rank misclassification. When correctly adjusting for the empirical market risk parameter, nearly 18% of all private market funds in our sample (465 out of 2,646) change performance quartile. The effect is more pronounced for buyouts where more than 26% shift quartile (289 out of 1,096) move quartile, compared to 11% of venture funds (176 out of 1,550 in our sample). The turbulence is most pronounced in the middle of the distribution, where approximately one-fourth of all second- and third-quartile funds are misclassified by standard metrics. More critically, the beta-adjustment completely reshapes the composition of the industry’s highly coveted top quartile. Under standard unadjusted metrics, 661 funds achieve top-quartile status. However, upon applying the proper risk-adjusted discount factor, 79 of these funds (12%) are demoted to lower quartiles. Under a strategy-level beta adjustment, a substantial fraction of funds move across performance quartiles, indicating that the unit-beta restriction materially affects allocation-relevant rankings. Economically, these managers did not generate superior alpha or exhibit exceptional skill; rather, they took on excessive market risk ($\beta > 1$) during a procyclical bull market, and the standard PME calculation granted them a performance premium.

Conversely, our methodology identifies 173 “hidden gems” (see first and second column of *Table 5 in the appendix*), funds that are classified as second- and third-quartile under standard PME but are promoted into a higher quartile under PME_β . These managers constructed portfolios with more conservative, lower-beta risk profiles. Because standard PME forces a universal $\beta = 1$ assumption across all cash flows, the performance under the beta-adjusted benchmark generated by these lower-risk funds was therefore penalized and obscured.

Ultimately, these quartile transitions show that adjusting for systematic risk is not merely an academic exercise in precision. Relying on standard PME creates a structural adverse selection problem for LPs: it systematically rewards managers who lever up on embedded market beta, while penalizing those who generate genuine risk-adjusted alpha.

6 Discussion

Our findings contribute directly to the ongoing debate in the PE literature regarding the adequacy of existing performance evaluation measures, notably the PME. Standard PME methods, despite their widespread industry adoption and simplicity (Kaplan and Schoar, 2005; Harris et al., 2014), inherently assume that private equity investments carry identical systematic risk to broad public markets ($\beta = 1$). Our study fundamentally challenges this assumption, empirically demonstrating that private market strategies systematically carry greater market exposure, significantly higher betas, than previously acknowledged. This finding builds directly upon foundational work questioning the accuracy of conventional risk adjustments within private equity performance assessment (Franzoni et al., 2012; Driessen et al., 2012). Furthermore, it directly corroborates recent advances in PE asset pricing, notably Gupta and Van Nieuwerburgh (2021), who utilize a strip-based valuation model to demonstrate that PE cash flows exhibit substantially higher equity risk premiums than standard benchmarks imply, and Ghysels et al. (2025), who confirm that the vast majority of PE return variation is spanned by public market factors.

Our methodological innovation, estimating beta parameters through the generalized PME ratio estimator, addresses the critical literature gap identified by Phalippou (2014) and Ang et al. (2018), who explicitly called for more precise, economically grounded methodologies for PE performance measurement. Crucially, our cash-flow-based framework offers a vital structural counterweight to recent econometric and survey-based performance literature. Recent studies employing state-space nowcasting models to un-smooth interim Net Asset Values (NAVs) (Brown et al., 2022), as well as broad empirical surveys comparing various performance metrics (Brown et al., 2025), frequently estimate U.S. buyout market betas closer to 1.0. By optimizing our estimator directly on terminal cash flows, we bypass interim NAV smoothing entirely, revealing that the embedded leverage and procyclical exit timing of these funds result in a significantly higher implicit market exposure than regression-based NAV adjustments suggest.

By formalizing the timing wedge (S), we provide the mathematical mechanism driving this bench-

marking distortion. We observe that standard PME substantially overstates fund-level alpha, primarily because managers time distributions to coincide with strong public market conditions. This empirical dynamic quantifies the cyclical distribution behaviors recently documented by [Brown et al. \(2021\)](#), while resonating strongly with prior theoretical models that highlight the procyclical nature of PE exits ([Gompers and Lerner, 2000](#); [Axelson et al., 2013](#)). Moreover, our analysis of the systematic directionality of this bias complements and expands the pioneering insights of [Korteweg and Nagel \(2016\)](#), confirming that valuation distortions are directly driven by the correlation between fund cash flows and market valuations. Ultimately, this operationalizes the forceful critique raised by [Phalippou \(2020\)](#), suggesting how boom-time cash flows, when discounted at $\beta = 1$, synthesize “fake alpha” out of levered market exposure.

Perhaps most critically, our examination of quartile rank turbulence implied the severe capital allocation consequences overlooked by conventional PME assessments. While broad surveys ([Brown et al., 2025](#)) emphasize a high top-quartile concordance across different performance metrics, our analysis indicated that aggregate rank stability masks severe, localized capital misallocation. The identification of widespread quartile misclassification expands upon prior critiques by [Sensoy et al. \(2014\)](#), [Harris et al. \(2014\)](#) and [Harris et al. \(2023\)](#), who documented potential misclassification issues but did not explicitly quantify the extent of capital misallocation.

By systematically overstating returns from procyclical, high-beta funds, standard metrics inadvertently encourage institutional capital flows into riskier investment profiles at the expense of truly skilled, risk-adjusted alpha generators. This confirms that the historical performance persistence documented in traditional PE literature may frequently be a persistence in unpriced market risk, or “lucky beta”, rather than genuine manager skill.

Nevertheless, our study also draws on some limitations which should be noted. First, the current draft relies on the Russell 3000 and S&P 500 as its maintained baseline benchmarks; robustness to further public-equity benchmarks can be extended. Second, although the one-factor beta adjustment is economically interpretable and tractable, it is not intended as a complete model of private-market risk. Third, while our holdout and weighting/vintage robustness checks support the central findings, the estimates remain conditional on terminal NAV treatment for non-liquidated funds.

In conclusion, our findings build directly upon the existing PE literature, offering rigorous empirical validation and significant methodological advancements. We underscore the imperative for both academia and practitioners to move towards more nuanced, risk-adjusted performance evaluation frameworks, better aligning performance measurement with economic realities and thus fostering more informed, efficient capital allocation decisions in private markets.

7 Conclusion

This paper challenges the ubiquitous assumption in private market benchmarking that fund cash flows carry systematic risk equivalent to broad public equities ($\beta = 1$). By applying a Generalized PME ratio estimator to a comprehensive sample of over 2,600 buyout and venture funds, we demonstrate that estimated benchmark-implied exposure parameters significantly exceed this standard. Crucially, when aggregated cash flows are discounted using these empirically derived, risk-adjusted parameters, the apparent historical outperformance of the private market asset class is fully subsumed by its compensated market risk. We show mathematically and empirically that this benchmarking distortion is systematically driven by a cash-flow timing wedge. Because fund managers naturally exit investments during procyclical public market peaks, the standard PME’s failure to apply a sufficiently high discount rate to these boom-time distributions mechanically synthesizes the illusion of alpha.

Most importantly, we quantify the economic consequences of this valuation bias for institutional capital allocation. By demonstrating that nearly a fifth of all funds shift performance quartiles when properly risk-adjusted, including the demotion of 12% of ostensibly “top-quartile” funds, our results reveal a structural adverse selection problem embedded within modern private equity allocation. Standard metrics systematically reward managers whose outperformance is an artifact of “lucky beta” rather than genuine skill, while simultaneously penalizing more conservative alpha generators.

Ultimately, our findings underscore the critical imperative for LPs and practitioners to transition toward beta-adjusted performance frameworks. Continuing to rely on unadjusted metrics not only obscures the economic realities of private market risk but fundamentally impairs the efficient allocation of institutional capital.

These conclusions should nevertheless be interpreted relative to our maintained benchmark choice and one-factor specification, both of which provide a parsimonious first-pass framework rather than a complete account of private-market risk.

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8 Figures and Tables

Figure 1: Performance Mismeasurement: Predicted and Realized Performance Bias under the $\beta = 1$ Restriction

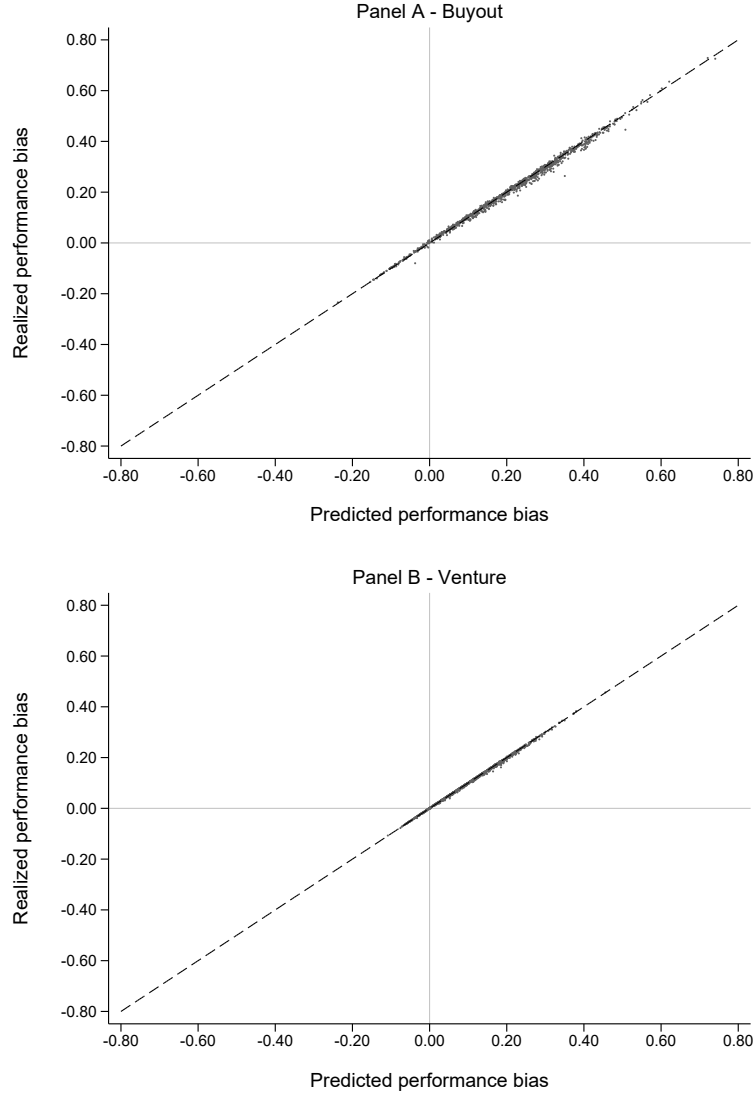


Figure 1 plots the realized fund-level performance bias against its first-order sufficient-statistics approximation separately for buyout (Panel A, $n = 1,096$) and venture (Panel B, $n = 1,550$). The vertical axis reports realized bias, defined as $\ln PME_i(1) - \ln PME_i(\hat{\beta}_{g(i)})$. The horizontal axis reports predicted bias, given by $-(\hat{\beta}_{g(i)} - 1)S_i$, where S_i denotes the fund-specific timing wedge. Positive values indicate that the standard PME benchmark overstates performance relative to the exposure-adjusted benchmark. The tight clustering around the 45-degree line shows that the interaction between non-unit systematic exposure and procyclical cash-flow timing accounts for most of the observed cross-sectional variation in performance mismeasurement. R^2 of 0.9962 for buyout and 0.9991 for venture respectively.

Table 2: Strategy-Level Pooled PME Ratios: Benchmark robustness

	Russell 3000		S&P 500	
	Buyout	Venture	Buyout	Venture
No. Funds	1,096	1,550	1,096	1,550
Estimated $\hat{\beta}_g$	1.6487	1.2974	1.6512	1.2825
Bootstrap SE	0.0907	0.0637	0.0918	0.0621
Bootstrap avg. $\hat{\beta}_g$	1.6556	1.2987	1.6591	1.2839
95% CI	1.4797–1.8397	1.1744–1.4284	1.4776–1.8453	1.1616–1.4080
Curvature	0.1808	0.4400	0.1835	0.4636
No. holdout funds	554	777	554	777
Holdout pooled PME($\beta = 1$)	1.2291	1.1532	1.2274	1.1467
Holdout pooled PME($\hat{\beta}_g$)	0.9970	0.9891	0.9855	0.9842

Table 2 reports the baseline strategy-level beta estimates for buyout and venture funds using the Russell 3000 Total Return Index (first and second column) and the S&P 500 Total Return Index in comparison, together with bootstrap uncertainty, curvature diagnostics, and holdout-sample pooled PME validation.

Table 3: Risk-Adjusted PME: Weighting robustness

Strategy	Weighting	$\hat{\beta}$	Deviation	Curvature
Buyout	equal	1.6487		0.1808
Buyout	call	1.6309	1.08%	0.1788
Buyout	sqrt(calls)	1.6334	0.93%	0.1791
Venture	equal	1.2974		0.4400
Venture	call	1.2878	0.74%	0.4369
Venture	sqrt(calls)	1.2919	0.42%	0.4385

Table 3 represents the robustness of the $\hat{\beta}$ based on different weighting. In the first specification, equal weighting, each fund receives the same weight in the strategy-level objective, so the estimated beta reflects the average pricing error across funds rather than being dominated by larger vehicles. The second specification weights each fund by its total capital calls, so larger and more heavily invested funds contribute more to the beta estimate than smaller funds. The third weighting is a square-root-of-calls weighting. Here, each fund is weighted by the square root of total capital calls, which gives more influence to larger funds than equal weighting but dampens their dominance relative to full calls weighting. Results indicate that the estimated strategy-level beta is highly stable across alternative weighting schemes, indicating that the main buyout and venture results are not driven by weights or fund size.

Table 4: Risk-Adjusted PME: Vintage Year robustness

Strategy	Weighting	Vintage	$\hat{\beta}$	Curvature
Buyout	equal	1984–1999	1.7318	0.2300
Buyout	equal	2000–2009	1.6012	0.1398
Buyout	equal	2010–2021	1.4618	0.2920
Venture	equal	1984–1999	1.2936	0.4380
Venture	equal	2000–2009	1.0416	0.3719
Venture	equal	2010–2021	1.7837	0.4572

Table 4 re-estimates the strategy-level β separately within broad vintage-year subsamples to assess whether the main results are stable across different fundraising and market environments. It shows that the main result, beta estimates above or around one and often materially above one, persists across vintage cohorts, although the magnitude of systematic exposure varies over time, especially for venture.

Table 5: Quartile Transition Matrix: Standard PME vs. Risk-Adjusted PME

Panel A - Buyout					
PME_1	PME_β				Total
	Top	Q2	Q3	Bottom	
Top	225	49	0	0	274
Q2	49	166	59	0	274
Q3	0	58	179	37	274
Bottom	0	1	36	237	274
Total	274	274	274	274	1,096

Panel B - Venture					
PME_1	PME_β				Total
	Top	Q2	Q3	Bottom	
Top	357	30	0	0	387
Q2	30	322	36	0	388
Q3	0	36	329	22	387
Bottom	0	0	22	366	388
Total	387	388	387	388	1,550

Panel C - Combined					
PME_1	PME_β				Total
	Top	Q2	Q3	Bottom	
Top	582	79	0	0	661
Q2	79	488	95	0	662
Q3	0	94	508	59	661
Bottom	0	1	58	603	662
Total	661	662	661	662	2,646

Table 5 presents the transition matrix of fund performance rankings for 2,646 private market funds. It maps funds from their quartiles based on the standard Kaplan-Schoar PME (PME_1) (rows) to their quartiles based on the risk-adjusted PME_β (columns). Bold diagonal cells indicate funds that remain in the same quartile under both measures, while off-diagonal elements represent misclassification by the standard metric.