Asset pricing robustness in venture capital

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Abstract

We provide robust evidence that traditional asset pricing models fail to incorporate key idiosyncratic properties of Venture Capital (VC) contracts under no proper risk-adjustment, leading to significant pricing heterogeneity relative to market participants. An option pricing analysis of 2,056 US VC-backed companies with 9,188 deals confirms that holding period and equity volatility are primary factors optimizing investor risk and return metrics, and minimizing valuation heterogeneity regardless of deal or contracting characteristics. We provide a security-return design evaluation framework leading to robust value attribution between investors, founders, and employees, and harmonized risk bifurcation across securities with asymmetric payoff properties. We link standard deviation of assets to key VC contract properties and leverage structural risk signals of VC contracts in optimizing endogenous derivation of investor risk premiums. Our results are robust and scalable to the broader VC universe.

Keywords: Venture capital, Contracts, Capital structure, Value of firm, Asset pricing.
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1. Introduction

Venture capital (VC) contracts have been instrumental in the optimal resolution of agency issues between founders and investors, and the generation of excess returns fueling massive financial growth and economic expansion over the last decades, as illustrated in Figure 1. They are key in the functioning of private markets. On the other hand, VC contracts are typically linked to a variety of economic rights reflecting varying levels of investor downside protection and asymmetric, state-contingent payoff structures. The complexity of VC contracts, illiquid investment nature, and limited financial or valuation disclosures from portfolio companies of VC funds (VCs), has led to increased valuation dispersion between market participants and appraisers. As a result, VC investments pose first-order challenges for asset pricing and valuation.

Despite the importance of VC as an asset class, there is striking dispersion in how identical VC securities are valued across investors, appraisers, and reporting institutions. Market participants often rely on post-money valuations (PoMV) implied by financing rounds, while valuation professionals constrained by accounting standards and regulatory guidance, typically employ option pricing valuation models. Existing evidence documents large and systematic differences between these approaches (Gornall and Strebulaev (2020), Gornall and Strebulaev (2021) and Agarwal et al. (2023)), particularly for securities with strong investor-friendly rights. This valuation heterogeneity raises fundamental questions about whether prevailing asset pricing frameworks appropriately capture the risk and return characteristics of VC securities.

This paper argues that a key source of valuation disagreement arises from misspecified risk adjustment. On the one hand, at least 9 out of 10 VCs surveyed by Gompers et al. (2020) believe that valuation of unicorns[1] are overstated. On the other hand, standard asset pricing models frequently impose exogenous assumptions on volatility, holding periods, discount rates, and capital structure without proper evaluation of implied risk-return properties relative to organic VC characteristics and foundations of VC security design. In particular, commonly used option pricing method (OPM) treats VC securities as contingent claims valued under risk-neutral dynamics, leading to substantial divergence from risk-adjusted organic VC return expectations. We provide novel comprehensive evidence that a large portion of the observed pricing disparity between investors and appraisers, is typically linked to lack of proper risk-adjustment of key asset pricing assumptions.

We develop a security-return-level asset pricing framework to address this gap. We treat each VC investment as a portfolio of equity securities mirroring cash flow rights tied

[1]VC-backed companies with reported PoMV over $1 billion.

to VC contracts, aiming to isolate risk-sharing attributes linked to investors' capital repayment vs. upside profit participation. We reconcile standard private credit portfolio returns for the downside protection of investors linked to fixed payoff, achieving proper risk bifurcation between investors capital protection and profit sharing with founders and employees in value enhancing scenarios. This framework explicitly separates returns attributable to capital repayment from those associated with upside participation, allowing for a coherent reconciliation of preferred equity returns with standard private credit benchmarks on the downside and equity-like payoffs on the upside. Rather than imposing volatility exogenously, we infer the risk embedded in the standard deviation of assets endogenously from investor return requirements, allowing for multi-variables adjustment considering business stage, contracting properties, deal and capital structure characteristics, and model specifications affecting distribution of exit outcomes. Optimization of preferred security return metrics minimizes security value differential between old vs. new investors, founders and employees, by harmonizing the probabilistic assessment of optimal liquidity outcomes across the full capital structure.

We are the first to leverage risk signaling of VC contracts, as a proxy of idiosyncratic risk, embedded in investor returns, and enhance valuation robustness of investments with strong investor-friendly contracts. Our findings have important implications. First, they provide a unified explanation for persistent valuation gaps between market participants and appraisers, particularly in late-stage investments with strong investor protection rights. Second, they suggest that commonly used option pricing approaches can materially misprice VC securities when applied without proper contract risk adjustment. Third, our framework scales naturally across various stages, deal characteristics, and other contracting properties, making it applicable to a broad cross-section (as in our empirics) of the VC universe which also extends to the broader private equity (PE) spectrum. These insights are directly relevant for financial reporting, tax valuation, secondary transactions, and the design of VC contracts.

An important contributing factor to asset pricing challenges is the endogenous risk-sharing behavior tied to VC contracting design with asymmetric risk exposure characteristics. Standard VC contracts align diverging economic interests between founders, employees and investors (Townsend (1979), Grossman and Hart (1986), Baker (1992), Berglöf (1994)), and allow for dynamic incorporation of future dilution in anticipation of strategic synergistic added value and abnormal returns upon qualifying exit events (Cornelli and Yosha (2003), Inderst and Mueller (2004), Hall and Woodward (2010)). VCs add value to portfolio companies by developing value enhancement activities that cover broader organizational efficiency and financial health aspects (Chemmanur et al. (2011)), proper risk-sharing equity incentive programs (Hellmann and Puri (2002)), and strategic executive human capital management (Ewens and Marx (2017), Lerner (2022)), among primary organic and add-on acquisition growth initiatives. VCs develop corporate monitoring mechanisms leveraging technological developments (Ewens et al. (2018)), broader social and macroeconomic variables (Ewens and Farre-Mensa (2022)) as well as idiosyncratic investment and company specific considerations (Sahlman (1990), Xuan (2011), Broughman and Fried (2012)) that have been repeatedly tied to performance persistence (Hochberg et al. (2013), Buchner et al. (2016), Harris et al. (2023)). Preferential reduced acquisition costs (Hsu (2004)), risk-taking contracting orientation (Litov et al. (2024)) tied to VC reputation and consistent focus on influential managerial decision-taking access via Board of Directors (BoD) presence (Amornsiripanitch et al. (2019)) reflect default VC strategy elements. Continuous emphasis on adaptive add-on funding strategies (Hogrebe and Lutz (2024)), heavy weight concentration on quality attributes of founding teams (Bernstein et al. (2017)), and strategic allocation of powerful control rights with tangible liquidity implications (Cumming (2008)), shape investment performance characteristics tied to VC contracting. Top VC-backed companies have been systematically tied to the generation of excess returns, overcompensating investors for the increased idiosyncratic risk and illiquidity (Gompers and Lerner (1997), Chen et al. (2012), Brown and Kaplan (2019)).

When considering illiquid VC investment properties and limited financial information access, market participants and appraisers typically rely on pricing information of financing events (either new financing rounds or large-scale secondary offerings) that could be considered arm's length transactions[2]. Investors typically oversimplify pricing implications and rely on PoMV of VC-backed companies on a fully diluted (FD) basis ignoring key VC contracting characteristics, and treating all classes as common-stock equivalent (CSE) shares. On the other hand, appraisers take a fundamentally different approach, bound by specific accounting reporting requirements and asset pricing guidelines introduced by the Accounting Standard Codification Topic 718 and 820[3], the 2019 American Institute of Certified Public Accountants Guide for the valuation of illiquid private investments (2019 AICPA Guide)[4], the Internal Revenue Code Section 409(a), and associated Treasury regula-

[2]Participation of new institutional investors and a substantial volume size are deemed essential to qualify for an arm's length transaction.

[3]Refer to FASB ASC 718 – Compensation – Stock Compensation and FASB ASC 820 – Fair Value Measurement.

[4]The 2019 AICPA Guide for the *Valuation of Portfolio Company Investments of Venture Capital and Private Equity Funds and Other Investment Companies* provides comprehensive guidelines and best practices for the valuation of equity securities in privately held companies, which pose several challenges to valuation appraisers and audit teams due to (i) the lack of marketability of PE securities, (ii) the complex capital structures, and (iii) the absence of market value indications that would serve as reliable model calibration inputs.

tions (IRC 409(a))[5]. The most prevalent and widely accepted approach by appraisers for the valuation of multi-share VC capital structures with various contracting properties is the OPM, which is based on the foundations of option pricing theory and the contingent claim analysis introduced by Black and Scholes (1973) and Merton (1974). The OPM treats the different equity classes as derivative instruments on the total assets of the company with strike prices reflecting the appropriate participation threshold of each security, depending on the contractual economic rights and privileges and the company capital structure details.

This paper contributes to three strands of the literature. First, we contribute to the growing literature on asset pricing in VC. Prior work applies contingent-claims models to VC-backed firms and documents systematic discrepancies between reported valuations and economically adjusted values. We extend this literature by demonstrating that a substantial share of this value differential can be traced to improper risk bifurcation of contractual rights and value split between investors, founders, and employees. We propose a novel security-return framework that leverages risk signaling of contracts and investor expectations, leading to more optimal reconciliation of VC properties. We are also the first to address more systematically valuation implications of illiquidity for founders and employees, based on broadly accepted pricing models and assumptions. Our paper resonates closely with Gornall and Strebulaev (2020), who apply the contingent model of Black and Scholes (1973) and Merton (1974) to 135 unicorns and measure valuation deviation relative to reported PoMV as of the latest financing round, and Agarwal et al. (2023), who apply a similar model, initially introduced by Metrick and Yasuda (2010b), to marks of private companies included in mutual funds and conclude on an average 43% discount on consolidated asset value levels. Agarwal et al. (2022) investigate how asset pricing of illiquid holdings affects mutual funds reporting. Korteweg and Nagel (2016) suggest a novel stochastic discount factor model for VC assets, while Sorensen et al. (2014) develop an asset pricing model leading to risk-adjusted valuations after accounting for capital allocation, liquidity and transferability constraints. Gornall and Strebulaev (2021) suggest an alternative model that considers future dilution of subsequent capital raised based on default deal assumptions and Opp (2019) links asset pricing to investor preferences and broader macroeconomic variables. Korteweg and Sorensen (2010) and Brown et al. (2022) suggest novel risk-adjusted models that consider valuation reporting frequency and asymmetric payoff characteristics, while Gupta and Van Nieuwerburgh (2021) link the impact of hybrid capital structures to risk adjusted return and valuation metrics. Hillenbrand and Stafford (2025) leverage real option theory and treat VC-backed firms as portfolio of

[5]Refer to IRS Section 409(a).

compound options, while Berger et al. (1996) introduce a dynamic real option framework linking investor preferences to optimal liquidity periods and dynamic VC strategies.

Second, we contribute to the extensive literature on VC contracting and agency theory. While prior research shows how hybrid securities optimally allocate control and incentives, we document that those contractual features materially affect asset pricing through their impact on investors' effective risk exposure. Our analysis links contracting design directly to valuation outcomes, highlighting the asset pricing implications of default VC contracts, strong investor-friendly cash flow rights, and staged financing. Our paper closely relates to the research of Kaplan and Stromberg (2003), Bengtsson and Bernhardt (2014), and Fu et al. (2023) on the evolution of contracting properties over time and the existence of default contract in VC deal design, and Ewens et al. (2022), who analyze the impact of VC contracts for early stage businesses in optimal value creation and proper value attribution between investors and founders. Kalay and Zender (1997), Biais and Casamatta (1999), Bascha and Walz (2001), Cornelli and Yosha (2003), and Schmidt (2003) address why hybrid securities are foundational for VC contracts and optimal organic value outcomes. Bengtsson and Sensoy (2011) provide robust evidence about the importance of board representation for skilled VCs as key contracting property leading to enhanced portfolio monitoring, building on earlier work of Kaplan and Stromberg (2004) on structural contracting considerations depending on VC focus on monitoring and corporate governance mechanisms. Bengtsson and Sensoy (2015) find a negative correlation between financial performance and investors friendly cash flows rights. Broughman and Fried (2010) analyze implications of common stock ownership in eventual exit payoff characteristics and potential alteration of initial governing rights, while Bengtsson and Ravid (2009) investigate the impact that the location of portfolio companies has in contracting details and Geczy et al. (2021) note the alignment of control and governance rights with impact-related objectives signaling contract adaptive behavior to social impact factors.

Finally, we contribute to the literature on risk and return in PE and VC. Existing studies document performance persistence, heterogeneity in risk-adjusted returns, and the role of illiquidity and market timing. We provide a complementary perspective by showing how contract-induced risk bifurcation between downside protection and upside participation helps reconcile observed return patterns with security-level risk characteristics across stages and market conditions. Our paper validates empirical findings of Cochrane (2005) about lower risk-adjusted returns associated with lower idiosyncratic risk of late stage VC ventures, despite asset volatility persistence. Yimfor and Garfinkel (2023) highlight different factors driving VC performance measurement and expected return characteristics for late vs. early stage ventures. Kaplan and Schoar (2005) document VC performance persistence, while Barber and Yasuda (2017) link persistence to VC asset management strategies, liquidity properties, and insights from interim asset valuation disclosures. A large number of studies including Ljungqvist and P. (Ljungqvist and P.), Phalippou (2013), Jovanovic and Szentes (2013), Harris et al. (2014), Kaplan and Sensoy (2015), Jegadeesh et al. (2015), Korteweg (2019), Ang et al. (2018), Korteweg (2019), Brown et al. (2021), Brown et al. (2022), and Gredil et al. (2023) document superior returns for PE assets. Nanda and Rhodes-Kropf (2013) address the impact of market signals and the timing of initial capital raise in VC risk-adjusted performance and Puri and Zarutskie (2012) evaluate risk evolution during VC assets life-cycle. Lerner (1994) investigates the impact of market timing into VC exit decisions and implied return metrics and Nguyen and Vo (2021) analyze the relationship between market liquidity and VC asset performance.

Overall, this paper provides a contract-adjusted asset pricing framework for VC that improves valuation robustness, and offers new insights into how risk, return, and contract design interact in private markets, aiming to minimize asset pricing heterogeneity.

The remainder of this paper is organized as follows. Section 2 describes the mathematical framework for the valuation of VC-backed assets and derivation of analyzed risk properties. Section 3 provides an overview of the sample construction and valuation principles. Section 4 summarizes the impact of VC contracting on value properties and security characteristics, while Section 5 addresses asset pricing robustness. Section 6 discusses the significant implications for practice, while Section 7 concludes.

2. Venture capital asset pricing model

In this section, we outline the fundamental properties of our model and its related parameters. Section 2.1 provides the OPM mathematical derivation, while Section 2.2 includes the description of the examined risk and return metrics. Section 2.3 describes key contracting properties while Section 2.4 summarizes leveraged option pricing assumptions.

2.1. Mathematical framework

Let us consider a VC-backed company that has undergone N financing rounds. Each financing round date is denoted with t_n, $n = 1,\dots,N$, and the company has issued j_n different preferred stock classes. The proposed pricing framework relies on valuing each security class as a combination of call options written on the equity value of the company (EV)[6], denoted with E_t at time t, under the assumption that the company would pursue an exit event

[6]A summary of all abbreviations is provided in Appendix C.

at a predetermined date. The liquidity date is denoted by T, and for each financing round, the expected liquidity horizon is equal to $\Delta t_n = T - t_n$. The selection of this parameter is typically an endogenous decision related to a multivariate function of several variables including equity concentration, investors' preferences and risk tolerance properties, and optimal market conditions.

The EV of the company, E_t, follows a geometric Brownian motion process with the following specification:

$$dE_t = rE_t dt + \sigma E_t dW_t, \quad E_0 = E > 0 \tag{1}$$

where r denotes the risk-free rate of return, σ is the equity volatility, and dW_t denotes the increments of a standard Brownian motion process. The aforementioned stochastic process ignores dividends, since typically VC-backed assets are not tied to periodic dividend distributions, and any declared dividend is properly accounted in the eventual payoff amounts of the preferred stock classes as of the liquidity date. We define the value of each security as the expected payoff as of the liquidity date, discounted at the risk-free rate of return that corresponds to the assumed liquidity term. The payoff function of each security is a non-linear function of the underlying asset price, and in particular, a piecewise linear function of the terminal equity value, reflecting various contracting properties and relative capitalization structure dynamics. Therefore, the payoff of the j-th equity security as a function of the company's EV is mathematically expressed as:

$$\pi_j(E_T) = \int_0^{E_T} \omega_j(x)\,dx, \quad j = 1, \ldots, j_n \tag{2}$$

where $\pi_j(\cdot)$ denotes the payoff function and $\omega_j(\cdot)$ represents the participation ratio of the j-th equity class. The participation ratio function is a piecewise linear function of the terminal equity value and behaves as a step function once a specified participation threshold is reached. In the industry parlance, these equity value thresholds or equilibrium value thresholds that trigger participation ratio adjustments are referred to as breakpoints. For example, a conversion breakpoint reflects the EV threshold at which it is economically optimal for a preferred shareholder to exercise the conversion option and elect to convert their original preferred stock into CSE shares to realize a better exit payoff.

To illustrate the properties of the participation ratio $\omega_j(\cdot)$, consider a VC-backed company with a capital structure consisting of two classes of convertible preferred stock (Series A and B) and a class of common stock. Series B is senior to Series A, which is senior to common stock, and both classes are convertible into CSE shares based on a 1.0x conversion ratio. The first breakpoint relates to the repayment of the preferential liquidation preference (LP) of Series B. Subsequently, Series A is entitled to the unreturned LP. Then, common stock is entitled to any distribution amounts until the EV level at which it is economically beneficial for the preferred stock with the lower conversion price (CP) to convert. CP typically mirrors the original issue price (OIP) of a preferred stock class, adjusted for LP properties or downround anti-dilution properties. Assuming a normal upround such that $OIP_B > OIP_A$, the next EV threshold reflects the Series A conversion breakpoint with an imminent dilutive effect to the participation ratio of common stock, based on the Series A CSE shares. Similarly, the last EV threshold is the Series B conversion threshold that introduces a step down adjustment to the effective participation ratios or both Series A and common stock for any incremental distribution amount. The aforementioned dynamic adjustment of effective payoff rights is illustrated graphically in Figure 2.

To generalize this example, we can leverage the set of breakpoints, denoted by B_i ($i = 1,\ldots,i_n$, and i_n is the total number of breakpoints), to separate the integrals into subintervals within which the weight is constant and equal to ω_i. Thus, we can express the payoff function as:

$$\pi_j(E_T) = \int_0^{\min(B_2,E_T)} \omega_j(x)\,dx + \sum_{i=2}^{i_n-1} \int_{\min(B_i,E_T)}^{\min(B_{i+1},E_T)} \omega_j(x)\,dx + \int_{\min(B_{i_n},E_T)}^{E_T} \omega_j(x)\,dx, \tag{3}$$

where the first breakpoint $B_1 \equiv 0$, and the 'min' ensures that the formula is correct, $\forall E_T > 0$. Within each integral, the weights of all equity securities are constant, as x lies between two consecutive breakpoints. If ω_{ji} is the weight of the j-th security between breakpoints i and $i+1$ (and ω_{ji_n} is the weight of the j-th security above the final breakpoint), then we can simplify the payoff to:

$$\begin{aligned}\pi_j(E_T) = \omega_{j1}\min(B_2,E_T) + \sum_{i=2}^{i_n-1} \omega_{ji}\left(\min(B_{i+1},E_T) - \min(B_i,E_T)\right) \\ + \omega_{ji_n}\left(E_T - \min(B_{i_n},E_T)\right).\end{aligned} \tag{4}$$

We can express the payoffs (4) in a matrix form:

$$
\begin{pmatrix} \pi_1(E_T) \\ \vdots \\ \pi_{j_n}(E_T) \end{pmatrix} = \begin{pmatrix} \omega_{11} & \cdots & \omega_{1i_n} \\ \vdots & \ddots & \vdots \\ \omega_{j_n 1} & \cdots & \omega_{j_n i_n} \end{pmatrix} \cdot \begin{pmatrix} \min(B_2, E_T) \\ \vdots \\ \min(B_{i+1}, E_T) - \min(B_i, E_T) \\ \vdots \\ E_T - \min(B_{i_n}, E_T) \end{pmatrix}, \tag{5}
$$

or more compactly: $\boldsymbol{\Pi}(E_T) = \Omega_n \cdot \boldsymbol{\Delta B}(E_T)$.

The weights of the different stock classes are independent of the EV and they only depend on the set of breakpoints. The $(j_n \times i_n)$ matrix of weights, Ω_n, is referred to as the allocation matrix. Thus, the following relation must hold: $\sum_{j=1}^{j_n} \omega_{ji} = 1, \forall i \in \{1, \ldots, i_n\}$, or in matrix form, $\Omega_n \cdot \boldsymbol{e_i} = 1, \forall i \in \{1, \ldots, i_n\}$, where e_i is the i_n-dimensional unitary vector along the i direction, i.e., the vector with the i-th element equal to 1 and all the others equal to 0. The total value of the economic payoff is equal to the underlying asset price, which is the EV. Since the primary motivation of the OPM is to bifurcate the consolidated asset value to the various stock classes, we replicate the payoff structure of the company's stock classes by utilizing a theoretical portfolio of European call options. Each call option value reflects the net upside beyond the applicable breakpoint. The positive incremental delta between two consecutive option calculations represents the net value associated with the risk-neutral probability that the ending EV lies within the designated breakpoints. Each incremental call option value is allocated to the company's stock classes based on the proper participation ratios, as specified by the allocation matrix. Let us consider the last breakpoint, above which all securities participate on a pro-rata basis. The payoff above the i_n-th breakpoint is $\pi^{(i_n)}(E_T) = \max(E_T - B_{(i_n)}, 0)$. Here, we use the superscript to distinguish payoffs between breakpoints from payoffs of securities (where we use a subscript). Later, we will use the notation π_j^i to denote the allocation of the payoff between breakpoints i and $i+1$ to the j-th security. This payoff is equivalent to the payoff of a call option with strike price $B_{(i_n)}$. Its present value (as of a financing round date t_n) using risk-neutral valuation is:

$$
\begin{aligned}
e^{-r(T-t_n)}\pi^{(i_n)}(E_T) &= e^{-r\Delta t_n}\mathbb{E}\left[\max(E_T - B_{(i_n)}, 0)\right] \\
&= e^{-r\Delta t_n}\mathbb{E}\left[\begin{cases} E_T - B_{(i_n)}, & E_T \geq B_{(i_n)} \\ 0, & E_T < B_{(i_n)} \end{cases}\right] \\
&= e^{-r\Delta t_n}\int_{B_{(i_n)}}^{+\infty} (x - B_{(i_n)}) f(x)\, dx,
\end{aligned} \tag{6}
$$

where $\mathbb{E}[\cdot]$ denotes expectation w.r.t. the risk-neutral density $f(x)$ of EV:

$$f(x) = \frac{1}{x\sigma\sqrt{\Delta t_n}\sqrt{2\pi}} \exp\left\{-\frac{(\ln x - \ln E_{t_n} - (r - \frac{\sigma^2}{2})\Delta t_n)^2}{2\sigma^2 \Delta t_n}\right\}, \tag{7}$$

with E_{t_n} being the equity value as of the financing round date t_n, so that

$$e^{-r\Delta t_n}\pi^i(E_T) = e^{-r\Delta t_n}\int_{B_{i_n}}^{+\infty}(x - B_{i_n})\frac{1}{x\sigma\sqrt{\Delta t_n}\sqrt{2\pi}}e^{-\frac{(\ln x - \ln E_{t_n} - (r-\sigma^2/2)\Delta t_n)^2}{2\sigma^2\Delta t_n}}\,dx$$

$$= e^{-r\Delta t_n}\int_{\frac{\ln(B_{i_n}/E_{t_n}) - (r-\sigma^2/2)\Delta t_n}{\sigma\sqrt{\Delta t_n}}}^{+\infty}\left(E_{t_n}e^{(r-\sigma^2/2)\Delta t_n + u\sigma\sqrt{\Delta t_n}} - B_{i_n}\right)\frac{1}{\sqrt{2\pi}}e^{-u^2/2}\,du$$

$$= E_0 N(d_1) - B_{i_n}e^{-r\Delta t_n}N(d_2) \equiv C(E_{t_n}, B_{i_n}, r, \sigma, \Delta t_n),$$

where $N(\cdot)$ is the cumulative standard normal distribution, and its arguments, d_1 and d_2, emerge as integration limits when transforming to the standard normal distribution:

$$d_{1,2}(E_{t_n}, B_{i_n}, r, \sigma, \Delta t_n) \equiv \frac{\ln(E_{t_n}/B_{i_n}) + (r \pm \sigma^2/2)\Delta t_n}{\sigma\sqrt{\Delta t_n}}. \tag{8}$$

We can express the EV as the sum of the consecutive call option values that measure the net value attributable to interim payoff functions between consecutive breakpoints. The present value (as of t_n) of the expected payoff between breakpoints i and $i+1$ is equal to:

$$\begin{aligned} e^{-r\Delta t_n}\pi^i(E_T) &= e^{-r\Delta t_n}\begin{cases} 0, & E_T \le B_i \\ E_T - B_i, & B_i < E_T \le B_{i+1} \\ B_{i+1} - B_i, & B_{i+1} < E_T \end{cases} \\ &= e^{-r\Delta t_n}\int_{B_i}^{B_{i+1}}(x - B_i)f(x)\,dx + e^{-r\Delta t_n}\int_{B_{i+1}}^{+\infty}(B_{i+1} - B_i)f(x)\,dx \\ &= C(E_{t_n}, B_i, r, \sigma, \Delta t_n) - e^{-r\Delta t_n}\int_{B_{i+1}}^{+\infty}(x - B_{i+1})f(x)\,dx \\ &= C(E_{t_n}, B_i, r, \sigma, \Delta t_n) - C(E_{t_n}, B_{i+1}, r, \sigma, \Delta t_n). \end{aligned} \tag{9}$$

We now have all the necessary components to calculate the present value of each stock class. The present value of the j-th security between breakpoints i and $i+1$ is:

$$e^{-r\Delta t_n}\pi_j^i(E_T) = \omega_{ji}\left(C(E_{t_n}, B_i, r, \sigma, \Delta t_n) - C(E_{t_n}, B_{i+1}, r, \sigma, \Delta t_n)\right), \tag{10}$$

and the present value of the j-th security is the sum over all i:

$$
\begin{aligned}
e^{-r\Delta t_n}\pi_j(E_T) &= e^{-r\Delta t_n}\sum_{i=1}^{i_n}\pi_j^i(E_T) \\
&= \sum_{i=1}^{i_n-1}\left[\omega_{ji}\left(C(E_{t_n},B_i,r,\sigma,\Delta t_n)-C(E_{t_n},B_{i+1},r,\sigma,\Delta t_n)\right)\right] \\
&+\omega_{ji_n}C(E_{t_n},B_{i_n},r,\sigma,\Delta t_n),
\end{aligned} \tag{11}
$$

We can write the present values of all the securities in a matrix form:

$$
e^{-r\Delta t_n}\begin{pmatrix}\pi_1(E_T)\\ \vdots \\ \pi_{j_n}(E_T)\end{pmatrix} = \begin{pmatrix}\omega_{11} & \cdots & \omega_{1i_n}\\ \vdots & \ddots & \vdots \\ \omega_{j_n1} & \cdots & \omega_{j_ni_n}\end{pmatrix}\cdot\begin{pmatrix}E_{t_n}-C(E_{t_n},B_2,r,\sigma,\Delta t_n)\\ \vdots \\ C(E_{t_n},B_i,r,\sigma,\Delta t_n)-C(E_{t_n},B_{i+1},r,\sigma,\Delta t_n)\\ \vdots \\ C(E_{t_n},B_{i_n},r,\sigma,\Delta t_n)\end{pmatrix}. \tag{12}
$$

The first and last inputs of $\Delta C(E_T)$ are also differences between call options. The first input has a strike price of 0 (denoting that there is no negative distribution amount) and the last input has a strike price of $+\infty$, with values E_{t_n} and 0. The present value of the j-th equity security is given by $e^{-r\Delta t_n}\pi_j(E_T) = e_j^L \cdot \Omega_n \cdot \Delta C(E_{t_n})$, where the superscript L denotes the transpose of a matrix and e_j is the j_n-dimensional unitary vector along the j direction. Since we perform the analysis as of the latest financing round, we typically solve to determine the level of EV that calibrates the value of latest issued preferred stock class to its stated OIP. If the index N corresponds to the latest issued preferred stock, then its present value using the OPM is $e^{-r\Delta t_n}\pi_N(E_T) = e_N^L \cdot \Omega_n \cdot \Delta C(E_{t_n})$.

2.2. Risk and return metrics

In this section, we introduce the valuation implied risk and return metrics analyzed in order to determine asset pricing robustness. These metrics include (i) the risk-neutral internal rate of return (IRR) or implied yield (LPY) associated with the discounted LP of preferred stock, (ii) the ratio of downside protection (DP) or present value of LP, relative to the aggregate value of preferred stock, (iii) the conversion probability (CPR) of the various stock classes, (iv) the asset value delta (AVD) defined as the relative % difference between EV and PoMV, and (v) the security value delta (SVD) denoting the delta between the value of the last preferred stock relative to another specified security (either preferred stock or common stock). Those risk-neutral observations should reconcile properties of VC investment strategies, idiosyncratic asset characteristics, and broader market participant considerations for illiquid PE asset classes.

An important contribution of the current paper relative to existing literature, is that all the preferred investments can be represented as a portfolio of two bifurcated instruments (i) junior or mezzanine debt component that covers the LP properties and mirrors return expectations of private credit instruments, plus (ii) an upside component in the form of an equity sweetener via options with adjusted strike price reflecting specific preferred stock properties. More specifically: (a) a convertible preferred stock entails an upside in the form of an adjusted strike price or breakpoint that reflects the contractual CP, (b) a participating preferred stock is associated with an upside feature in the form of an attached common stock (the adjusted strike price reflects the aggregate level of LP of all preferred stock classes), and (c) non-convertible, non-participating preferred stock instruments have effectively zero upside.

LP yield (LPY): This metric measures the risk-neutral implied IRR tied to the successful repayment of the unreturned capital contribution, adjusted for any other LP characteristics (i.e., dividends, multiple etc). It is calculated by treating the present value of the LP, implied by the OPM, as the value of the debt component, and the total LP as the expected repayment value at the liquidity date. The contemplated IRR should consider the private nature of the contemplated VC asset and yield indications attributable to private credit instruments or firms with similar growth and risk characteristics. At time t_n (the present as of the n-th financing round), the value of the LP component is $e^{-r\Delta t_n}\pi^i_j(E_T)$. Assuming that at time T_n, the value equals LP_j, we calculate an implied IRR to the bond component of the equity security j as of the n-th financing round:

$$LPY_{jn} = \left(\frac{LP_j}{\omega_{ji}\left(C\left(E_{t_n}, B_i, r, \sigma, \Delta t_n\right) - C\left(E_{t_n}, B_{i+1}, r, \sigma, \Delta t_n\right)\right)}\right)^{\frac{1}{\Delta t_n}} - 1. \tag{13}$$

The return metric (13) is not intended to capture the consolidated return of preferred stock classes, but instead isolates the yield attributable to the debt component, as a relative benchmark between the latest issued preferred stock and remaining preferred stock classes and a measure of idiosyncratic risk properties of market participants entering the contemplated (or similar) transactions.

Downside protection (DP): This variable measures the relative bifurcation of preferred stock value between downside (mezzanine bond component) and upside feature (conversion feature) and is calculated as the ratio of the present value of the LP relative to the consolidated value of the underlying class. VCs aim to realize a target yield via abnormal returns attributable to the conversion feature - they do not just aim for capital or LP repayment. Those return expectations should be bifurcated as of the measurement date to reflect proper risk sharing attributes for the two aforementioned separate features. Subsequent successful financing activity typically leads to lower DPs due to price inflation and higher common stock in-the-moneyness. A heavy concentration of economic outcomes triggering only DP claims, unless it refers to abnormal LP characteristics (i.e., 2.0x multiple or 15% paid-in-kind (PIK) rate), might indicate improper balancing of market participants expectations. If the stock class j receives its LP_j, between breakpoints i and $i+1$ after the n-th financing round, then its present value is essentially the difference of the consecutive call options multiplied by the security percentage allocation of the underlying stock class between those breakpoints:

$$e^{-r\Delta t_n}\pi_j^i(E_T) = \omega_{ji}\left(C(E_{t_n}, B_i, r, \sigma, \Delta t_n) - C(E_{t_n}, B_{i+1}, r, \sigma, \Delta t_n)\right), \tag{14}$$

and DP is calculated as the portion of the value attributed to the bond component:

$$DP_j = \omega_{ji}\left(C(E_{t_n}, B_i, r, \sigma, \Delta t_n) - C(E_{t_n}, B_{i+1}, r, \sigma, \Delta t_n)\right) \Big/ V_j. \tag{15}$$

Conversion probability (CPR): This metric denotes the probability that (i) a preferred stock class will convert into common stock triggering exercise of the attached conversion feature or (ii) the common stock is in-the-money, as applicable. This measure is particularly important, because the probabilistic assessment of superior return outcomes might be understated under a risk-neutral framework relative to standard market participant assumptions based on the successful financing history, anticipated liquidity event, and remaining liquidity horizon. Additionally, a relative analysis of the derived conversion likelihood of the various stock classes provides meaningful insights about asset pricing robustness when compared with standard VC strategies and typical investment payout characteristics. If the j-th preferred stock class is converted into CSE shares at breakpoint B_{i_j}, then the CPR for this security is defined as the $N(d_2)$ applicable to the conversion breakpoint, i.e., $P(E_T > B_{i_j}) = \int_{B_i}^{+\infty} f(x)\,dx = N\left(d_2\left(B_{i_j}\right)\right)$, where $d_2(B_i) = \left(\ln\left(E_{t_n}/B_{i_j}\right) + \left(r + \sigma^2/2\right)\Delta t_n\right) / \left(\sigma\sqrt{\Delta t_n}\right)$.

This metric also applies to common stock to infer the likelihood that common stock holders receive any residual asset value upon full repayment of consolidated LP claims.

Asset value delta (AVD): The EV implied by the OPM is typically lower than the PoMV, due to the bifurcation of the different contracting properties of stock classes, unless there is a substantially low conversion ratio for one or more preferred stock classes, which is extremely rare. The level of valuation dispersion between the two valuation indications, tied to both specific contracting details and modeling assumptions, provides significant pricing information about the model robustness and appropriateness of option pricing assumptions. To quantify this difference for a financing round associated with issuance of preferred stock i, we introduce the AVD metric, defined as $AVD_i = \frac{EV_i}{PoMV_i} - 1$. While material AVD differences might be explainable due to the existence of non-standard strong investor rights or increased idiosyncratic risk, they usually represent the first indicator of a potential misalignment in implied VC risk attributes, especially for established and successful VC-backed companies.

Security value delta (SVD): Similar to AVD motivation, this metric measures the value differential between the last preferred stock j_N relative to another specified stock class, either prior preferred stock or common stock. Successful VC funding history with consolidated OIP inflation round over round, leads to organic expectations for lower value differential between consecutive preferred stock classes (under similar VC economic terms) and a harmonized delta of consolidated preferred risk properties relative to common stock. Substantial delta is linked to potential improper modeling of VC outcomes or improper risk-attribution analysis within the capital structure. This metric is measured as follows: $SVD_{N,j} = \frac{V_j}{V_N} - 1$. Here, we can also replace V_j by V_C to measure value delta relative to common stock.

2.3. Contracting groups and payoffs

In addition to the analysis of the consolidated VC sample, we analyze separately the impact of two key contracting groups to isolate the impact of VC contract design in value, risk and return characteristics. The first contracting group relates to the preferred stock type, which is typically split into convertible or participating (non-participating and non-convertible preferred stock classes are rare in VC equity portfolios since they effectively represent venture debt claims). The primary difference between those two securities is the embedded upside feature. In the case of convertible preferred stock, the upside is in the form of an attached call option with an underlying strike price equal to the CP. In the case of participating preferred stock, the upside is linked to an attached common stock claim (the upside participation ratio of both types can be different than 1.0x depending on the underlying CR). The expression of the economic payoff of those claims for a preferred security j is:

$$\mathbf{e}_j^L \cdot \Omega_n \cdot \Delta\mathbf{B}(E_T) = \left(0,\ldots,0,\omega_{j,i_{\mathrm{LP}}},0,\ldots,0,\omega_{j,i_{\mathrm{conv}}},\ldots,\omega_{j,i_n}\right)\cdot\Delta\mathbf{B}(E_T), \quad \text{if convertible,} \tag{16}$$

$$\mathbf{e}_j^L \cdot \Omega_n \cdot \Delta\mathbf{B}(E_T) = \left(0,\ldots,0,\omega_{j,i_{\mathrm{LP}}},0,\ldots,0,\omega_{j,i_{\mathrm{comm}}},\ldots,\omega_{j,i_n}\right)\cdot\Delta\mathbf{B}(E_T), \quad \text{if participating,} \tag{17}$$

where $B_{i_{\mathrm{LP}}}$ and $B_{i_{\mathrm{LP}+1}}$ are the breakpoints related to the repayment of the contractual LP, $B_{i_{\mathrm{conv}}}$ marks the respective conversion breakpoint, $B_{i_{\mathrm{comm}}}$ reflects the breakpoint at which common stock starts accruing value, and

$$\omega_{ji} = \mathrm{CR}\cdot\omega_{\mathrm{comm},i},\ \forall i \geq i_{\mathrm{conv}}, \quad \text{if convertible,} \tag{18}$$

$$\omega_{ji} = \mathrm{CR}\cdot\omega_{\mathrm{comm},i},\ \forall i \geq i_{\mathrm{comm}}, \quad \text{if participating.} \tag{19}$$

The second contracting group relates to the order of LP claims leading to senior or pari-passu preferred stock classes. Senior securities have a priority in any capital distributions in accordance with their contractual LP relative to other preferred stock classes and common stock claims, while pari-passu preferred stock classes are entitled to the same order of distributions based on LP-weighted relative participation ratios. The economic payoff of such a preferred security j_n, where n>1, is as follows:

$$\mathbf{e}_{j_n}^L \cdot \Omega_n \cdot \Delta\mathbf{B}(E_T) = \left(1,0,\ldots,0,\omega_{j_n,i_{\mathrm{conv}}},\ldots,\omega_{j_n,i_n}\right)\cdot\Delta\mathbf{B}(E_T), \quad \text{if } j_n \text{ senior,} \tag{20}$$

$$\mathbf{e}_{j_n}^L \cdot \Omega_n \cdot \Delta\mathbf{B}(E_T) = \left(\omega_{j_n,1},0,\ldots,0,\omega_{j_n,i_{\mathrm{conv}}},\ldots,\omega_{j_n,i_n}\right)\cdot\Delta\mathbf{B}(E_T), \quad \text{if } j_n \text{ pari-passu.} \tag{21}$$

This relationship refers to convertible preferred structures, but by default also applies to participating structures based on adjustment of the respective upside properties. Capital structures might be subject to various seniority patterns; two or more preferred stock classes may hold pari-passu economic claims and be senior or junior to other preferred stock classes. If a set of X of preferred stock classes are pari-passu and receive their LP between breakpoints $B_{i_{\mathrm{LP}}}$ and $B_{i_{\mathrm{LP}+1}}$, then $\omega_{j,i_{\mathrm{LP}}} = \mathrm{LP}_j \cdot \left(\sum_{j\in X}\mathrm{LP}_j\right)^{-1}, \quad \forall j \in X$

2.4. Option pricing assumptions

Option pricing assumptions are of significant importance in the derivation of risk-adjusted return metrics and mispricing characteristics. The standard assumptions leveraged in our analysis are described as follows:

Volatility: Given that the OPM asset price is the implied EV of the company, this metric should reflect the re-levered equity volatility σ. Considering the lack of public trading history for private VC-backed assets, this assumption is typically based on the volatility analysis of a set of guideline public comparable companies (GPC). Implied unlevered asset volatility is derived by solving for an asset volatility and equity volatility that satisfy both equations of Merton (1974), given each company's leverage, and the same process is repeated for the determination of the re-levered volatility of the VC-backed asset by accounting for the company-specific leverage profile. Given that the GPC typically consists of more mature companies with potentially substantial differences in risk and return characteristics, there is subjectivity in the selection of the assumed asset volatility metric, the quantification of any applicable size premium, and potentially an underestimation of the true idiosyncratic risk profile. In our analysis, we leverage a volatility range between 30% to 150% to quantify the magnitude of pricing heterogeneity linked to option pricing assumptions. We suggest that volatility should be derived endogenously based on VC contract risk signaling characteristics and reconcilision of default VC risk properties, as noted in Sections 5.1 and 5.2, respectively. Appropriate parameter selection should consider as a floor the level of standard deviation implied by minimum return expectations of investors.

That volatility floor should be calculated based on consideration of organic return on equity (ROE) expectations of market participants considering the financing history and underlying growth characteristics. This method can be used across a number of different variables[7], and derives an implied risk-adjusted volatility metric from the capital asset pricing model (CAPM) by (Sharpe, 1964): $\sigma = \frac{\sigma_m \times \beta_i}{\rho_i}$, where σ_m denotes the long-term volatility of the market index (e.g., S&P 500), β_i denotes the indicated beta coefficient of the VC-backed company versus the broader market index, and ρ_i is the correlation coefficient (set to 1 for purposes of determining the floor) [8]. To infer a beta-specific ROE volatility, we rely on average ROE expectations per VC growth stage, considering reported industry PE return studies like the Pepperdine studies [9] and conclusions of Gompers et al. (2020) and Brown et al. (2022).

Exit timing: While there are general VC investment horizon targets in connection with certain return multiples or IRR thresholds, the actual liquidity horizon depends on the underlying strategy, fund, idiosyncratic properties as well as broader market and industry variables. In our analysis, we leverage a liquidity horizon Δt_n range since the last preferred

[7]Refer to the fourth edition of the Contingent Consideration Guide (p. 60, lines 1783-1811).

[8]If the VC ROE is 25% and the risk-free rate of return is 2.5%, then the implied risk premium is 22.5%. Assuming a market risk premium of 6%, the implied company-specific equity beta is 3.75. Multiplying the equity beta by the assumed long-term volatility (e.g., the historical volatility of the S&P 500 - 18% assumption for this example) yields a floor equity volatility of 67.5%.

[9]For the most recent Pepperdine private cost of capital survey, please refer to this link.

stock financing between 1 to 10 years to quantify asset pricing disparity. Our suggested risk-adjustment solutions in Section 5.2 rely on a 5 year exit horizon, which is consistent with Metrick and Yasuda (2010b), Gornall and Strebulaev (2021) and the average Initial Public Offering (IPO) timing reported in Hillenbrand and Stafford (2025). Considering that this is an exogenous parameter selection, consideration should be given to the risk-adjusted implied return properties of preferred stock classes. We provide clear evidence that optimal investment horizon election depends on both VC contracting properties and level of equity volatility utilized.

Risk-free rate: Considering that OPM relies on a risk-neutral framework, the drift of our model is the risk-free rate r corresponding to the assumed exit timing. Similar to prior studies, we use a base assumption across our sample to avoid differences in the interest rate environment that could lead to asset pricing deltas not purely related to the examined variables. Our base assumption is 3.0%, consistent with Agarwal et al. (2023) but we also perform a sensitivity analysis with a range varying between 1.0% to 5.0%, which captures assumptions leveraged in prior studies (2.5% in Gornall and Strebulaev (2020) and Gornall and Strebulaev (2021); 5.0% in Hillenbrand and Stafford (2025)) to establish asset pricing robustness.

3. Data and process

In this section, we describe our data collection and sample characteristics. Section 3.1 summarizes sample selection criteria, while Section 3.2 documents key sample properties. Section 3.3 outlines the primary sources for capital structure and VC contracts, and Section 3.4 addresses important valuation considerations related to the full sample.

3.1. Sample selection

For our sample construction, we relied on a novel and large dataset provided by Forge[10] including 2,764 U.S. VC-backed companies with detailed contracting and deal characteristics across all financing rounds. We have excluded from our sample companies linked to abnormally high or low LP multiples or conversion ratios that could not be validated with underlying operating agreements. Companies for which we could not reconcile the deal pricing characteristics of the latest financing round relative to the available capitalization structure properties, were also excluded. We also excluded companies associated with a

[10] Source: Private market data provided by Forge Data LLC, a division of Forge Global Holdings, Inc. ("Forge"). Forge is a leading provider of private market infrastructure, data services, and technology solutions.

last financing round leading to an issuance of a junior preferred stock, which is unusual and does not reconcile standard VC deal characteristics. Several companies have multiple deals recorded as of the same date; given that this is not a standard deal practice and there was not other information available to confirm if there was a conversion of any convertible notes or improper recording of certain deal properties or other strategic reasons leading to this outcome, those companies were also removed. Finally, we also removed from our sample companies with a single closed financing round, leading to a final sample of 2,056 VC-backed companies with 9,188 recorded deals or an average 4.5 rounds per company. Our sample accounts for both (i) companies with a successful exit activity, and (ii) companies without any principal exit liquidity transaction. We account for a broad variety of VC contracts, business stages, sectors, financing status, and VC performance attributes to eliminate any potential sub-sample or asset pricing bias. Our analysis focuses on the last consummated financing transaction for each company to maximize VC contracts population.

As discussed below in Section 5.4, our empirical findings apply to the broader VC spectrum regardless of sample selection, given the principal use of hybrid securities in the VC contract design (Bengtsson and Bernhardt (2014), Fu et al. (2023)), the standardization of cash flows and control rights, embedded risk and return attributes and limitations of asset pricing models to both idiosyncratic characteristics and parameter selection.

3.2. Sample characteristics

In this section, we present key characteristics of our VC sample. A detailed summary of sample characteristics is presented in Table 2 of Appendix A. Our sample accounts for a statistically significant size of both early and late stage ventures, with 25% (39%) of the companies associated with 6 or more (3 or less) financing rounds. About 76% of our sample is still private without any recorded exit transaction, while the remaining sample has contemplated at least one exit transaction, either public or private. Panels C and D validate findings of Bengtsson and Bernhardt (2014) and Fu et al. (2023), confirming the existence of default VC contracts, with 92% convertible and 66% pari-passu properties considering full financing history. About 79% of our sample has an average financing round period of up to 2 years, which aligns with observations of Gornall and Strebulaev (2021), Gornall and Strebulaev (2021), and Hillenbrand and Stafford (2025). A total number of 738 companies out of the 2,056 have an average deal size across all financing rounds higher than \$5 million and only 3.4% of our sample exceeds average deal size of \$20 million, which validates organic expectations given the population of early vs. late stage companies and differences between funding sizes across business stages. The percentage of companies with capital raised during the last round higher than \$20 million is 3.7x higher (12.7%) relative to the average deal amount, while 36% of our sample raised at least \$10 million during the last financing transaction. Only 11% of our sample has a ratio of deal size vs. PoMV as of the last financing round higher than 25%, while 41% has a ratio lower than 10%. Finally, from an asset price evolution perspective, 102 companies have a reported PoMV as of the latest financing round higher than \$500 million, while 66% of our sample has a reported valuation lower than \$100 million.

3.3. Capitalization structure and contracting information

VC contracting characteristics are typically incorporated in the Certificate of Incorporation (COI). The COI is a legal document that includes the formation governing principles of a new corporation and describes in detail the underlying economic rights and privileges of all equity classes authorized for issuance. Table 1 of Appendix A summarizes primary economic features attributable to preferred stock classes and the respective economic payoff characteristics. Not all attached economic rights have a tangible and quantifiable value under the financial reporting or tax requirements; the focus of the current paper is on the primary attached embedded cash flow rights that have significant pricing implications and are typically included in corporate valuations.

Our sample includes a summary of the primary contracting characteristics per financing round, primarily covering LP properties, type of preferred stock and underlying seniority. We fill-in the gap related to anti-dilution protection, by assuming that standard weighted-average anti-dilution provisions exist for all preferred stock classes, given that this feature constitutes a default VC contract provision (Fu et al. (2023)). The anti-dilution provision kicks-in upon the completion of a downround. Assuming that the pre-money valuation ($PrMV$) in connection with the issuance of a preferred stock j is $PrMV_j$, then a downround typically occurs when $PrMV_j < PoMV_{j-1}$, with $j > 1$, which assuming no stock-split or other substantial capitalization structure change is also reflected in $OIP_j < OIP_{j-1}$ and $CP_j < CP_{j-1}$. We calculate the adjusted CP of any preferred stock j_1 after the completion of a subsequent j downround as follows: $CP'_j = CP_j(N_{j-1} + \frac{PoMV_j - PrMV_j}{CP_j})/N_j$, where CP_j is the CP prior to the downround, CP'_j is the CP after the downround, N_{j-1} is the total number of CSE shares before the downround, and N_j is the total number of CSE shares after the downround.

Deal size (DS) information is provided by Forge for the financing history of each company. Assuming that a company issued a preferred stock j for a specific DS, the following relationship holds: $PoMV_j = PrMV_j + DS_j$, and we extract the number of outstanding shares for each preferred stock class j as of each financing date, based on the following formula: $N_j = \frac{DS_j}{OIP_j}$. Then, we extract the missing information about the total pool of common stock (net of as converted preferred stock) as of the last financing round N, as follows: $N_C = \frac{PoMV_N}{OIP_N} - \sum_{j=1}^{N} \text{Original Shares}_j \times \text{Conversion Ratio}_j$.

Similar to how investors price deals and preferred stock classes, the common stock pool is inclusive of any options or management awards designed for employees. Typically, options' detailed information is not included in COIs and is difficult to be extracted due to limited information available for private companies. We sensitise to the impact of potential options grants in Section 5.4 and confirm that our findings are robust to this common valuation treatment.

3.4. Principal valuation assumptions

In this section, we discuss important VC valuation considerations typically considered by appraisers with implications for our full sample.

Single scenario OPM: A financing round calibration based on a single scenario OPM is typically a default approach for many appraisers, especially for early stage ventures. Given the limited information available for private companies, single OPMs typically capture variability in terms of both expected value outcomes and optimal exit strategy without introducing noise until there is specific quantifiable exit strategy. Consideration of dual path scenarios, with explicit modeling of potential IPO outcomes, is typically contemplated upon the issuance of an S-1 filing[11], which sends a clear signal about the intended liquidity outcome to market participants.

Static exit: Selection of a single investment horizon typically reflects default assumption for VC valuations, considering VC contracting, access to information, and market participant expectations. Unless there are term-structure driven variables (e.g., LP changes over time or options with dynamic market-based vesting conditions) or important business milestones driving binary value outcomes typically observed in certain sectors (e.g., pharmaceutical or biotech), the selected holding period typically reflects the weighted average holding period of all potential exit strategies and related liquidity periods.

Bifurcation of contracting features: While investors are entitled to a broad range of underlying economic rights, not all of them are analyzed for financial reporting or tax purposes. For example, rights of first refusal (ROFR) might be important for investors but do not necessarily affect the consolidated value of company's assets. Veto rights are also im-

[11] Registration statement required for companies that plan to go public.

portant, but it is difficult to quantify precisely their impact considering various potential complications (e.g., delay in IPO process which might affect pricing, change of exit strategy, renegotiation of primary cash flows rights, etc.). Our analysis captures all primary contracting rights following standard industry asset pricing principles to properly assess model robustness and parameter values.

Discount for lack of marketability (DLOM): While equity claims in VC-backed companies represent illiquid interests, appraisers do not typically apply any DLOM to preferred stock classes for financial reporting, due to the attached protection rights, consolidated preferred stock class equity concentration, and influential corporate governance and monitoring mechanisms. To a certain extent, any illiquidity considerations have already been embedded in the financing round pricing (i.e., OIP, ROE). On the other hand, common stock shares (options) typically owned by founders (employees) are usually subject to incremental discounts in accordance with standard 409(a) tax (ASC 718 financial) guidelines, considering principal differences in risk and liquidity properties. While there are several qualitative or quantitative DLOM approaches, some of the most widely utilized quantitative put option approaches are those introduced by Chaffe (1993), Ghaidarov (2009), Finnerty (2012), Longstaff (2001), and Longstaff (2018). The relative comparison of DLOM methods is out of the scope of this paper; however, we consider standard DLOM practices in Section 4.4, quantifying the impact of VC contracts on stock-based compensation.

4. Results

In this section, we present the results of our study. Section 4.1 summarizes the impact of contracting properties into value and return metrics. Section 4.2 highlights our findings on the reconciliation of key VC properties. Section 4.3 examines the relative value allocation between investors and founders, and Section 4.4 addresses the impact of VC contracts on stock-based compensation.

4.1. How VC contracts affect value and returns

VC contracts have significant implications in risk and value properties of investors and founders. Figure 3 summarizes our analysis across various contracting types and option pricing assumptions. Our findings on consolidated value properties across the full sample reconcile prior findings of Gornall and Strebulaev (2020), Gornall and Strebulaev (2021) and Agarwal et al. (2023). We observe that investor friendly contracts (i.e., senior or participating) lead to lower valuations and substantial delta relative to equity claims of founders or investors with junior securities. This relationship is observed in the form of a concave relationship across both consolidated asset level properties (Panels I-J) and security value characteristics (Panels K-N). Panel C suggests that senior VC contracts lead to disproportionate allocation of value in favor of downside coverage, leading to lower implied conversion probabilities and upside conversion value, which is verified by Panel E. Participating contracts bear significant dilution across the full capitalization structure with profound effects on observed AVD metric, as highlighted in Panel B.

The delta between investor-friendly and founder-friendly contracts becomes lower as idiosyncratic risk embedded in both volatility and term increases, leading to more harmonious risk attribution across participating classes. We observe that the upside participation feature has a higher beta in most of the analyzed risk properties relative to the seniority (comparison of rights vs left panels) under low option pricing assumptions. As optionality increases, we observe higher implied preferred yields (Panels A-B) and lower downside coverage (Panels C-D) leading to higher proportional value attribution to the conversion feature across all contracting groups. This relationship is accompanied by converging conversion probabilities between early versus late preferred stock. While conversion probabilities typically decrease under increased idiosyncratic risk (Panels E-H), the expected conversion value increases materially due to the impact of abnormal exit returns (in line with value implications of Panels C-D).

The aforementioned impact of the derived risk-neutral probability density function has an almost monotonic effect across all analyzed contracting groups. We find that both seniority and preferred type are linked to uniform evolution in key investors metrics like LPY (Panels A-B) and DP (Panels C-D). This statistical relationship holds despite higher asset pricing variation of other security or value metrics in low optionality environment, which is linked to both deal characteristics and model assumptions. This finding suggests that LPY and DP are key factors determining valuation robustness and reconciliation of VC performance properties.

4.2. Reconciliation of VC properties

We find that our analyzed risk and return metrics fail to capture key VC organic expectations for a large spectrum of option pricing assumptions. The level of deviation relative to default VC expectations is substantial, signaling significant valuation mispricing. Figure 4 summarizes our findings. We observe in Panel A that at least 87% of our sample has an implied preferred yield lower than or equal to 10% for volatility assumptions up to 50%, regardless of assumed holding period. Utilizing volatility and exit timing assumptions leveraged by Gornall and Strebulaev (2020) (Agarwal et al. (2023)), suggests that 41% (95%) of our sample is linked to a derived LPY lower than 15%. Considering the sample population with participating contracts typically linked to higher preferred yield expectations, the portion of founder-friendly contracts associated with low implied return properties becomes even more material. According to the 2019 AICPA Guide[12], typical venture private credit yields vary between 15% to 25%, reflecting a sizeable premium relative to public indexes, while broader VC equity IRR expectations are tied to higher premiums, as noted by Gompers et al. (2020), Brown et al. (2022). Rintamäki and Steffen (2025) finds that 50% of analyzed private loans have yields north of 10% and Rintamäki (2024) reports that the spreads of middle market loans better align with the first half of the suggested range by the AICPA Guide. Our analysis suggests that the yield gap relative to market participant expectations becomes less material under high optionality assumptions (i.e., volatility of 100% or higher and holding period or 5 or more years).

Similar findings are observed in the distribution of DP sample properties in Panel B. We document that low investment holding period yields a significantly high DP coverage across all contracting groups. This observation suggests heavily skewed distribution of exit payoffs, which are not properly aligned with historical recovery rates of VC investments and probability of zero or negative returns[13]. VCs anticipate abnormal returns associated with high exit valuations triggering the exercise of their contractual conversion features, in line with several studies (Kaplan and Schoar (2005), Jovanovic and Szentes (2013), Ang et al. (2018), Korteweg (2019), Korteweg (2019), Brown et al. (2021), Gredil et al. (2023) among others) and remarks of Puri and Zarutskie (2012) relative to performance of non VC-backed firms. They do not invest aiming to just recover their unreturned capital or LP. Any generated superior returns compensate VCs for the substantial risk related to company under-performance or distress. Thus, the bifurcation of value between downside and upside needs to properly reconcile investor driven payoff expectations and respective probabilistic assessment of exit asset value distribution. This is also clearly reflected in the distribution of CPR across various optionality scenarios (Panels C-D), indicating that the implied probability density function of the derived equity value resonates more closely with VC expectations as we increase both exogenous option pricing model parameters.

The consistent underestimation of VC risk attributes has significant implications in derived consolidated equity value characteristics and security specific metrics. Assuming a typical 5-year investment horizon, Panel E suggests that the probability that the implied

[12] Refer to paragraph B.04.03 of the 2019 AICPA Guide Appendix for more details.

[13] Refer to Paragraph 8.31 of the 2019 AICPA Guide and Metrick and Yasuda (2010b) for more details about actual statistics.

EV of a VC-backed company will be lower by up to 20% relative to the latest round PoMV increases by 3.38x (7.45x) moving from a 30% to 90% (120%) volatility. Similarly, the organic expectation about a de minimis value differential of successive preferred stock classes under a successful exit (assuming same contracting properties), is validated by the significant correction in the implied SVD indicated in Panel G, as idiosyncratic risk assumptions increase. The probability that the value delta of the last two preferred stock classes will be lower than 10% increases by 35% (96%) under the aforementioned option pricing assumptions. Further risk-adjustment of the assumed holding period yields a total increase of 196%.

4.3. Investors vs. founders

The relative value allocation between investors and founders depends on (i) deal characteristics, (ii) financing history and consolidated investor equity concentration as well as (iii) contracting properties and model parameters. Panel A of Figure 5 summarizes the impact of key investor metrics on the relative value ratio and implied common stock value per contracting group. We observe that the implied preferred yield has a material impact on all contracting groups, especially on investor-friendly ones. LPY increases are linked to increased conversion value and higher common stock in-the-moneyness due to abnormal returns related to fat-tail distributions. While each contracting group has its own beta, an increased yield tends to harmonize contracting or idiosyncratic risk differences, minimizing potential model limitations and sensitivity due to exogenous parameters and leading to harmonization of return properties across early and late stage investors as well as founders. An increase in the implied downside yield from the group of 5% to 15% range, to the range group of 25% to 35%, leads to an average 7% higher value allocation to founders across all contracting groups.

Similarly, we observe a negative correlation between DP and implied common stock value due to the inherent bifurcation of investor value between under-performing and over-performing exit value scenarios. A decrease in the implied DP from 90% plus range to levels between 55% and 65%, is associated with an average increase in the implied common stock value of 23%. Those findings validate organic expectations that increase of non-systematic risk leads to converge of risk properties across various shareholders, minimizing the impact of strong contracting rights. Under an optimal contract theory and in the context of standard agency issues between internal and external parties, this allows founders and employees to still be properly incentivized to maximize exit value outcomes and not look for alternatives given the higher opportunity cost.

Considering that value attributed to founders is highly dependent on deal size and financing history, we also investigate how the business growth stage and financing activity affects founders' value dynamics. Due to incremental dilution during each new financing round, there is a meaningful negative correlation between financing activity and weight of founders value. The correlation depends on both cumulative deal sizes associated with financing history and evolution of contracting characteristics. Senior and participating preferred stock across multiple rounds bear the highest cumulative dilution to founders. Panel B of Figure 5 highlight this relationship. While increased optionality could mitigate the impact of single financing round strong investor contracts, existence of such contracts over multiple rounds limits substantially the upside of founders requiring abnormally high levels of risk adjustment that alters substantially relative investor value dynamics. It is worth noting that despite the consolidated founders value differential across business stages, the implied discount of common stock relative to the last preferred stock is still highly dependent on the level of option pricing assumptions. Increased optionality harmonizes value delta between securities owned by investors versus founders, regardless of contracting properties or business growth. Considering this monotonic impact, the underlying discount across both contracting groups and business stages is subject to low standard deviation, signaling existence of similar risk properties across the sample of each group analyzed. This outcome is questionable considering the portion of VC-backed companies that either (i) close successfully subsequent financing rounds or (ii) consummate a successful exit event as well as fundamental differences in risk signaling of various VC contracts. This observation highlights the need for different level of risk adjustment and exogenous model parameter selection depending on both underlying growth status and contract type, which is addressed in Section 5.2.

Panel C of Figure 5 expands on the impact of each subsequent financing round. We observe that the median founders consolidated value percentage across the full sample reduces by -32% moving from ventures with up to 3 financing rounds to ventures with at least 8 financing rounds. This movement is primarily linked to the level of incremental dilution of each subsequent round and the ratio of DS relative to $PoMV$, and to a smaller extent to the actual performance of the business; down-rounds typically have a skewed impact on investors vs. founders value properties, leading to higher gap and incremental founders value dilution due to the disproportionate impact on subordinated equity claims.

4.4. Stock-based compensation

Our analysis so far has treated employees equity claims similar to founders, given the lack of access to the detailed capitalization structure and option granting history of VC-backed private companies. In this section, we aim to isolate the impact of VC contracts into stock based compensation based on select option grant assumptions and underlying industry valuation principles.

We assume that a company has granted as of the last financing round N a consolidated option pool of 10% based on an equal grant activity across the number of financing rounds. If the implied common stock pool is lower, then the effective option pool automatically decreases to that percentage. The strike price at each round n, $n = 1, \dots, N-1$, is determined as (i) 50% the OIP of that round multiplied by (ii) (1-$DLOM_C$), where the $DLOM_C$ factor represents the common stock specific illiquidity discount implied by the model of Finnerty (2012). For the purpose of this analysis, we use a DLOM estimation of 32.3%, which reflects the upper limit of the utilized model and is typically associated with equity claims under high holding period and volatility assumptions.[14] Contrary to prior studies (Gornall and Strebulaev (2020), Gornall and Strebulaev (2021) and Agarwal et al. (2023)), we quantify in a more dynamic way the value and return implications of illiquidity to founders and employees; we derive security specific discounts, endogenously derived based on the implied security specific standard deviation, which is a direct function of VC assumed risk, deal characteristics and option pricing assumptions. Since our asset pricing analysis is as of the last financing round N, the strike price for the options granted during that time is determined based on the implied value of the common stock, after further adjustment for the endogenous derivation of the common stock implied volatility and respective $DLOM_C$[15]. We sensitize those assumptions in Section 5.4 and validate that our findings are robust to variations in both option pool ownership percentage and strike price determination mechanisms. The number of common stock is adjusted accordingly to exclude the portion attributable to employee options.

Considering that options are derivative instruments on common stock, isolating their payoff leads to higher consolidated AVD metrics across the full contracting groups and universe of option pricing assumptions. On the other hand, the impact on security specific or investor return metrics is not material. As presented in Panel A of Figure 6, the risk properties of employees shares are closer to those of founders, and the derived gap becomes immaterial under increased optionality and especially for early stage ventures. A more

[14] Refer to Appendix B for more details about the DLOM framework

[15] The implied DLOM for the common stock as of the last round might be different relative to the assumed upper limit of the prior rounds, given that this is implied in a dynamic way from our asset pricing model.

material embedded differential in risk properties is observed in late stage ventures which are close to a liquidity event and have been subject to a significant asset price inflation over the cumulative financing history. While early option grants almost mirror value properties of founder classes, latest grants are highly sensitive to liquidity horizon and idiosyncratic volatility leading to sizable deltas in both consolidated asset value properties and security risk metrics under high option pool assumptions. Panel B of Figure 6 verifies our assumption that all else equal, substantial AVD typically linked to investor friendly rights leads to increased value differential for option holders relative to the last preferred stock investors. A relative evaluation of the two analyzed contracting groups suggests that contracts with higher seniority properties require higher level of risk-adjustment on either LPY or AVD to mitigate the incremental dilutive power relative to participating preferred contracts.

5. VC Reconciliation

In this section, we optimize parameter selection and calibrated variables to maximize asset pricing robustness. Section 5.1 analyzes the signaling and risk implications of contracts. Section 5.2 summarizes the results under proper risk-adjustment. Section 5.3 illustrates the regression results of key investor metrics and 5.4 describes our model robustness evaluation.

5.1. Contracts, signals and idiosyncratic risk

VC contracts signal certain levels of idiosyncratic risk assumed by VCs. Negotiation of strong investor-friendly contracts, especially for late stage ventures, typically arises from enhanced diversifiable risk rather than other strategic reasons[16]. All else equal, if a VC participates in two identical deals with different contracts (e.g. senior vs. pari-passu structure or convertible vs. participating), by definition they expect a different risk premium between the two deals, which should be sizeable considering the significant opportunity cost and the easy access to other similar deals. Contrary to prior studies utilizing flat asset volatility or holding period regardless of VC properties (Cochrane (2005), Metrick and Yasuda (2010b), Gornall and Strebulaev (2020), Gornall and Strebulaev (2021), Agarwal et al. (2023), Hillenbrand and Stafford (2025)), we suggest that both volatility and derived yield metrics should be adjusted to account for contract signaling with significant implications for the implied probabilistic distribution of exit outcomes. We test our hypothesis by using a with/without framework typically introduced when evaluating embedded

[16] Negotiated feature of lead investor or incremental value related to other key value contributions of VCs etc.

derivatives in assets or liabilities. We amend the properties of the 1,944 (1,631) convertible (pari-passu) structures to reflect participating (senior) properties and re-calibrate our asset pricing models to the last round preferred stock OIP. We use flat deal characteristics and model parameters to measure the impact of introducing an investor-friendly right into key investor metrics.

Figure 7 summarizes our findings that validate our hypothesis. Use of flat assumptions without contract risk-adjustment yields relative value properties not positively correlated with VCs expectations. The box-plot in the upper-left Panel A suggests that the median preferred yield delta is -2.5% for the convertible vs. participating structures under a 40% volatility assumption and a 4-year holding period, and changes slightly to -2.1% under an equity volatility of 100%. The spread follows investor expectations about higher idiosyncratic risk of participating contracts; however, the indicated spread is materially lower than the median delta between B and CCC corporate bonds as well as the delta between first and second lien term loans based on monthly data between 2005-2024, yielding a median spread of 630 and 547 basis points (bps)[17]. Similarly, the observed spread is 34% lower than the spread between first and second lien loans in leveraged buyout transactions according to Demiroglu and James (2010) and 32% lower relative to the spread between senior vs. junior debt per Colla et al. (2012). Given the subordination of equity claims relative to default debt claims, at least similar premiums (if not higher) are typically considered when dealing with equity claims of different seniority or fundamental differences in structural value mechanisms like the participating feature. Considering the significant dilution to founders by the addition of a participating feature, which becomes even greater if all preferred securities are participating, the negotiation of such deal is a clear indication of significant idiosyncratic risk that could not be hedged with other VC structures (seniority etc.). This feature also better emphasizes the nature of hybrid securities, and highlights the fixed downside payoff linked to LP as a subordinated mezzanine debt claim, while investors and founders share identical risk properties on the upside.

Our findings for the second contracting group (senior vs. pari-passu) further underscores the importance of contracts signaling into asset pricing risk adjustment. The box-plot in the lower-left Panel B indicates that the median preferred yield delta is 0.7% (4.4%) under an equity volatility of 40% (100%) and a 4-year investment horizon. Not only the absolute delta is lower than the spread of the aforementioned bond spreads, which becomes more relevant in cases of preferred securities with different seniority characteristics, but it also contradicts organic investor expectations about the relative risk profile of the analyzed contracts. While a market participant would consider a senior contract as a signal of

[17] PitchBook Data, Inc.; Data has not been reviewed by PitchBook analysts.

a riskier VC investment which would imply a higher effective discount rate or ROE, an isolated consideration of risk-neutral observations suggests that senior claims are less risky due to the higher effective downside coverage and implied probability of LP repayment. Downside coverage yields associated with those senior claims are very close to risk-free rates of return under no proper risk adjustment.

This economic reality fails to properly incorporate investors' perception about probabilistic capital recovery and firm's cumulative default probability, which serves as a foundation for contract negotiation and linkage of financial performance or idiosyncratic risk to contracting properties, consistent with Bengtsson and Sensoy (2015) and Hackbarth and Mauer (2011). Let us consider an investor contemplating an investment with target return ROE_t. If the investment has standard VC risk properties aligned with average VC portfolio benchmarks (ROE_t=ROE_d), the VC investor would accept a default pari-passu convertible contract, given that the implied LPY_d and DP_d would satisfy the risk tolerance conditions of the investor and the expected recovery amount (RA_d) under a distress scenario. If the VC investor deems that the assumed risk is higher (ROE_s>ROE_d), then under a risk-less portfolio with no arbitrage opportunities, they would structure the deal differently depending on the level of risk and the risk bifurcation between downside vs. upside scenarios. If the VC believes that it is likely that RA_s<RA_d, then they would propose a senior structure such at minimum their $LPY_s \geq LPY_d$, which suggests that also $DP_s \geq DP_d$. If this contract renegotiation is not sufficient, the VC would add incremental investor-friendly contracts (increased LP multiple, dividend yield, etc.), until an equilibrium of risk-adjusted LPY benchmarks has been achieved. Similarly, if there is limited upside, the investor would contemplate transferring portion of the ROE_t to the contractual LP in the form of incremental investor-friendly features. Natural extension of the aforementioned relationships, is that the implied distribution of potential exit outcomes or assumed standard deviation of assets between a default and a senior contract is different, all else equal; the differential depends on the contracting properties, which reflect discounted present value expectations about future liquidity outcomes. An extension of this relationship applies to convertible vs participating structures, with different underlying beta. Consistent with optimal contracting theory (Berglöf (1994), Bascha and Walz (2001), Cornelli and Yosha (2003), and Schmidt (2003)), we suggest that contracting information should be utilized as key information signal for purposes of deriving endogenously risk and return indications.

We note that each VC contract has a different beta to examined asset pricing assumptions, regardless of deal characteristics. The spread between investor-friendly and founder-friendly LPY metrics for the same firm reflects a diversifiable risk that could be controlled to a great extent by optimal selection of option pricing assumptions. The delta between convertible and participating structures suggests that risk adjustment in the form of volatility optimization only might not have a prevailing impact for medium or high risk investments, as suggested by the upper-right Panel A graph. A higher beta is observed in low risk assumptions embedded in short term liquidity windows and low asset standard deviation. On the other hand, volatility has a dominant role in the optimization of VC return properties when evaluating the LPY differential of senior vs. pari-passu contracts, as indicated by the lower-right Panel B graph. Lower level of asset specific adjustments are required to harmonize LPY delta across all the risk profiles, with a significantly higher beta in states of low risk. While optimal levels of value split between investors and founders could be achieved with abnormally low levels of optionality, due to the concave relationship highlighted in Section 4.1, risk adjustment robustness is linked to increased standard deviation of assets and holding period because of more harmonized derivation of VC exit outcomes.

Our findings suggest that volatility, and potentially holding period, should be linked to properties of VC contracts, instead of solely relying on default assumptions or set of public comparable companies. Figure 8 summarizes the delta of the median observed spread between senior and default VC contracts to option pricing assumptions after the aforementioned risk-adjustment to the subsample of senior contracts. We observe a monotonic relationship, which validates our hypothesis that contract risk signaling is independent of option pricing assumptions. We observe a median absolute volatility spread of 9.7% between senior vs. pari-passu contracts based on the full spectrum of option pricing assumptions, while very low exit timing assumptions backed up by extreme volatility could yield substantially higher spread (north of 20%). Our findings suggest that initial calibration of asset pricing models based on default VC contract characteristics and standard VC return expectations, could establish a benchmark reference for asset pricing robustness of investor-friendly contracts. Derivation of standard deviation of assets in an endogenous way for strong investor rights, instead of exogenous moderate risk assumptions, addresses any misalignment of return expectations embedded in default contract design mechanisms. Linking volatility to contract strength helps minimize pricing heterogeneity by controlling AVD levels and reconciling LPY with target investors return expectations.

5.2. Risk-adjusted valuations

Our analysis has clearly illustrated that valuations of VC-backed assets might be subject to significant mispricing of consolidated firm value or individual security properties, depending on the level of asset pricing assumptions leveraged. Lack of consideration of (i) contract signaling, (ii) investor forward-looking expectations, and (iii) relative market participant benchmarks, increases substantially the likelihood of a valuation heterogeneity. In this section, we offer an evaluation framework seeking asset pricing robustness based on calibration of different parameters; while there is no single right answer in the context of a private company valuation under the absence of a publicly traded security with statistically significant trading history, all the referenced optimization scenarios below are significant steps towards the direction of harmonizing risk-neutral valuations relative to market participants expectations.

Table 1 summarizes the findings of our risk-adjustment and concludes on the median risk and return metrics of the entire sample in each scenario. The base case illustrates the median valuation output of an average risk profile company backed by 40% equity volatility and a 3 year investment horizon, without any proper risk-adjustment. Panel A illustrates the impact of risk adjustment by optimizing derived preferred yield indications assuming a 5 year investment horizon, consistent with Metrick and Yasuda (2010a) and Gornall and Strebulaev (2021), and performing a double parameter backsolve process such that (i) the value of the last preferred stock is equal to the contractual OIP and (ii) the level of equity volatility calibrates the LPY to the stated level. If convergence is not achieved, an extension of the holding period and upward adjustment of the exogenous volatility is performed until calibration is reached. While selection of the lower bound yield (10%), which resonates better with median private credit yield reported by Rintamäki and Steffen (2025), does not bear any material risk-adjustment, increased yield premiums bear a substantial impact on risk-neutral metrics leading up to 29% lower implied median AVD and 43% lower median DP relative to the base case. Yield adjustments in the range of 15%-20% are better aligned with reported spreads for middle market credit instruments in the period of 2005-2022, as reported by Rintamäki (2024). The median implied standard deviation of the assets after calibration to the lower bound yield is 70.5%, which is about 10% higher than the volatility leveraged by Agarwal et al. (2023), while assumptions of Cochrane (2005), Gornall and Strebulaev (2020), Gornall and Strebulaev (2021), and Hillenbrand and Stafford (2025) better align with the standard deviation of 87.3% implied by the 15% downside yield. Leverage of 20% (25%) private credit benchmark yields implied volatility of 101.3%(113.4%) reflecting a meaningful premium relative to prior studies.

Same holding period assumption and calibration procedures apply to the remaining risk-adjustment scenarios, unless otherwise stated. Panel B (C) offers an alternative risk-adjustment solution by controlling for the implied probability density function using default market participants ROE assumptions for the implied equity volatility (security specific volatility). Using a range of ROE assumptions between 30%-40%, and deriving a beta equity volatility based on the formula described in Section 2.4[18], we document a significant improvement in the relative value properties between investors and founders. The first half of the utilized return range better aligns with reported ROE of VCs per Gompers et al. (2020) (29.0%-33.0%). Also, the standard deviation of assets leveraged by prior studies (Cochrane (2005), Metrick and Yasuda (2010a), Gornall and Strebulaev (2020), Gornall and Strebulaev (2021), and Hillenbrand and Stafford (2025)) is within the range of the endogenously derived volatility indications for such scenarios (85%-100%). Risk-adjusting for firm equity volatility leads to a decrease in the median $SVD_{N,C}$ by up to 26% and lowers the absolute delta between the median conversion probability of the underlying securities by up to 70%, when relying on the upper bound ROE, which matches VC returns reported by Brown et al. (2022). In the case of the derived preferred security volatility, the impact of risk adjustment is even greater. Median value attributable to founders increases by up to 30% at the end of the assumed ROE range, followed by a significant reduction in the relative median conversion probabilities of the last preferred stock and common stock by up to 78%[19], which better aligns with empirical observations of Hall and Woodward (2010) implying that in almost 75% of exits there is no incremental CPR difference across equity classes given zero cash flows to founders, and Broughman and Fried (2010) implying non-differential CPR indications across securities for a large portion of the analyzed sample with impaired LP realized values.

Up to this point, asset pricing adjustments have been performed without any explicit incorporation of different idiosyncratic properties related to early vs. late stage companies. Panel D addresses that by accounting for for different firm risk properties depending on business stage, consistent with Cochrane (2005), and assuming a constant spread between derived LPY between early vs. late stage ventures. Assuming a fixed spread of 10% between the aforementioned business stages, we analyze risk and return implications by using a LPY floor between 10.0% to 15.0% for early stage ventures. The spread accounts for fundamental differences in terms of risk profile, implied default probability, and monetization prospects. While it is reasonable to assume that early stage investments should be linked to higher ROE considering the higher non-diversifiable risk, from a valuation

[18] We leverage a standard deviation of 18.9% based on the 30-year trading history for S&P 500 as of 12/31/2024 and the base case risk-free rate of 3.0%.

[19] The differential of the median CPR_N and CPR_C as calculated separately based on the median of the full sample differs from the actual delta of those probabilities calculated first for each company and then based on the median descriptive statistic. However, given the monotonic impact of risk adjustment, the improvement in the reconciliation of value between investors and founders is still substantial based on the latter description which is the most appropriate one, leading to a median CPR delta of 71% (79%) in the case of firm equity volatility optimization (security specific volatility optimization). For purposes of auditing and backtesting solely by relying on the valuation output presented in Table 1, we present the former delta as a proxy.

perspective, the adjustment is in the opposite direction in a counterintuitive way. Incorporation of positive yield specific adjustment for early stage ventures would inflate value attributable to founders and smoothen value differential between investors and founders leading to an opposite risk adjustment effect. In reality, the effective risk-adjusted ROE applicable to early stage companies should be viewed as a probability and risk-adjusted yield expectation that already accounts for a higher cumulative dissolution probability. This is consistent with survey outcomes of Gompers et al. (2016) and Gompers et al. (2020), according to who most of the PE and VC funds leverage risk-adjusted return expectations. In our analysis, both the magnitude and direction of the spread are determined by asset pricing limitations embedded in the OPM. Proper risk adjustment for both preferred yield and company specific risk attributable to business stage leads to a lower AVD for late stage ventures by up to 31% relative to early stage ventures, which is also backed by a substantial 54% (32%) improvement in the $SVD_{N,N-1}$ ($SVD_{N,C}$) for such ventures.[20]

Another major novel contribution or our paper is risk adjustment on the grounds of contracting properties and risk signaling. As noted in Section 5.1, standard valuation procedures and flat pricing assumptions fail to capture contracting signal characteristics with significant value implications. An attribution analysis of value differential due to the incorporation of a strong investor friendly contract could address any value understatement due to improper risk balance. Panel E includes value properties for different contracting properties by leveraging a target LPY range for senior or participating contracts and analyzes the delta relative to default VC contracts. A significant correction across all metrics for investor friendly contracts is observed regardless of level of risk-adjustment. We note that leverage of a 20.0% yield benchmark leads to a 34% (28%) lower AVD ($SVD_{N,C}$) relative to the median equity value delta reported by Gornall and Strebulaev (2020) for the full sample. Similarly, our risk adjusted values for the last preferred stock relative to the immediately prior one ($SVD_{N,N-1}$), suggests that the delta is lower by 38% relative to average reported values by Agarwal et al. (2023). The observed correction is even higher in cases of greater LPY benchmark or added spread for investor-friendly contracts relative to founder-friendly ones. Incremental asset specific adjustments on the bench-marked yields

[20] While security value properties are positively aligned with the risk adjustment optimization rules applied, the relative conversion probabilities of securities included in early vs. late stage ventures do not necessarily reconcile organic expectations of investors. Considering that the CPR of a common stock class, for a late stage investment with successful financing history and consistent value appreciation round over round, should be higher relative to an early stage investment, any deviation unrelated to specific deal characteristics (i.e., change of VC contract, downround etc) suggests limitations of OPM and derived probability density function. To a certain extent, the impact of a lower positive exit probabilistic assessment is hedged by the impact of fat-tail distributions and extreme positive value outcomes; however a more robust derivation of alternative probabilistic and value exit outlooks for early vs. late stage ventures can be performed by incorporation of stochastic jump diffusion models or hybrid methods.

should be considered in the case of further enhanced investor friendly contracts (i.e., high LP multiples, high cumulative dividend yields etc.). Additionally, our analysis validates findings of Gornall and Strebulaev (2021) that issuance of new investor-friendly securities in subsequent rounds leads to great dilution on value claims of existing preferred securities rather than the common stock of founders[21], as illustrated by the $SVD_{N,N-1}$ delta for senior vs. pari-passu structures for each risk-adjusted scenario.

Contrary to studies leveraging flat volatility assumptions regardless of VC contract (Cochrane (2005), Metrick and Yasuda (2010b), Metrick and Yasuda (2010a), Gornall and Strebulaev (2020), Gornall and Strebulaev (2021), and Hillenbrand and Stafford (2025)), we find that optimal risk-adjustment for contract risk signaling suggests different implied standard deviation of assets per contract type. Figure 9 summarizes our findings. The implied equity volatility of senior contracts is on average about 5.0% higher relative to pari-passu contracts considering full spectrum of risk-adjustment scenarios between 10%-30% LPY, as presented in Panel A. We document that the spread has limited variability to option pricing assumptions. Any incremental yield expectations for increased idiosyncratic risk tied to further enhanced investor-friendly contracts, would yield even greater standard deviation spread. In the case of convertible vs. participating contracts, leverage of same IRR expectations yields a standard deviation of assets for participating structures lower between 3.6%-8.6% relative to convertible structures, all else equal, as presented in Panel B. However, given that participating structures are by default linked to higher LPY due to the greater dilution of the upside participation in the form of common stock, proper risk adjustment should consider an incremental spread. Adding a rounded spread of 3.5% aligned with observed private credit spreads of Demiroglu and James (2010) and Colla et al. (2012), suggests that an introduction of a participating feature, leads to a higher standard deviation relative to convertible contracts by an absolute range between 2.8%-8.1%, while an incremental spread of 5.0% leads to an increased volatility by an absolute spread of 6.1%-10.9%.

Finally, Panel F includes a risk-adjustment by a switch to a hybrid asset pricing model that aims to deal with limitations of single-scenario OPMs and derived probabilistic distribution of exit outcomes. In the recent years, hybrid models have gained popularity due to higher level of appreciation of OPM limitations in the context of VC valuations. Hybrid models allow for a separate modeling treatment of an IPO vs. a sale scenario allowing for different value dynamics and risk bifurcation across the various security classes. While

[21] This is typically described by appraisers as the "sandwich effect" of OPM. Preferred securities that are subordinated are meaningfully diluted by the issuance of new preferred securities with strong investor rights and their risk and return properties become closer to those of founders, especially under low-moderate option pricing assumptions

there are several forms of hybrid models, the default approach in cases of financing round calibration under the absence of any specific IPO exit pricing is the hybrid method in the form of a (i) going-concern sale scenario based on the standard OPM and (ii) a FD scenario leveraging the OIP of the last preferred stock round across the full capital structure. In other words, the IPO scenario represents the way that market participants price the underlying deals based on the PoMV under the assumption that all securities participate in exit proceeds on an as converted basis and share same value per unit. Assuming an IPO probability p as of the closing of the preferred stock N and for any preferred security $j = 1, \ldots, N$, the following relationships hold:

$$CEV_N = p * PoMV_N + (1-p) * EV_N, \tag{22}$$

$$CV_j = p * OIP_N * CR_j + (1-p) * V_j, \tag{23}$$

$$CCPR_j = p + (1-p) * CPR_j, \tag{24}$$

where CEV_N: probability weighted average concluded equity value of the company, EV_N: implied equity value derived by the OPM, CV_j: probability weighted average concluded value of preferred security j,CR_j: conversion ratio of security j, V_j: value of preferred security j derived by the OPM, $CCPR_j$: probability weighted average concluded CPR of the security j, CPR_j: CPR of preferred security j implied by the OPM. Replacing j with C yields probability weighted average indications attributable to common stock. Under an IPO scenario, given that all securities participate as FD shares, the implied CPR is set to 100%. LPY or DP metrics are not particularly meaningful for the hybrid approach considering underlying conversion assumptions. In this case, risk-adjusted option pricing assumptions have been utilized for the going-concern sale scenario based on a holding period of 5 years and 100% equity volatility. The assumed standard deviation better resonates with the upper bound of VC returns reported by Gompers et al. (2020), as also presented in Panel B.

Our analysis suggests that hybrid models could materially enhance valuation robustness by successfully mitigating OPM distribution limitations and deriving both (i) probabilistic exit distribution value outcomes and (ii) relative value indications that better reconcile the synthetic risk profile of consolidated equity claims in a VC-backed company. Effectively, hybrid models alter the implied probability density function of a single OPM by applying similar risk-sharing principles across the full capital structure, harmonizing implied CPRs between early preferred stock vs. late preferred stock as well as between investors and founders and limiting the skewness of strong downside cash flow rights. Low

(Increased) consideration of an IPO scenario with a probability of 25% (75%) combined with option pricing assumptions risk adjustment lead to a reduction in the median AVD by 56% (85%), increase value allocable to founders by 170% (236%) and reduce significantly CPR delta across multi-share capital structures to low double digits (single digits). The correction on the analyzed risk and return metrics is still significant net of the impact of proper risk adjustment for option pricing assumptions, based on a relative comparison with Panels A-C. Those findings suggest that proper risk adjustment of option pricing models or switch to hybrid models leads to diminished relative pricing disparity between appraisers and market participants for late stage ventures, which better resonates with Cochrane (2005) and Korteweg and Sorensen (2010) who leveraged PoMV valuation benchmarks and Fu et al. (2023), who suggested that those valuations are good proxies for established mature VC ventures, which are also associated with a higher IPO probability per Cochrane (2005) and Gornall and Strebulaev (2020).

5.3. Key valuation factors

We have provided strong evidence that LPY, DP and AVD are key factors determining valuation robustness and securities mispricing. In this section, we perform a regression analysis relative to select deal characteristics, asset performance measurement variables, and options pricing assumptions, to determine primary drivers shaping the aforementioned asset pricing outcomes. Table 2 summarizes the regression output for each analyzed risk and return metric.

Volatility and holding period are leading parameters driving asset pricing optimization for the analyzed investor metrics; holding period has a slightly lower importance in the case of LPY, while volatility has a dominant effect. While both option pricing assumptions have a positive correlation with AVD, the opposite relationship is observed in the case of DP, in line with organic variable construction expectations. The size of the last financing round DS_N has a statistically significant impact on both LPY and AVD metrics, leading to higher deviation of risk-neutral metrics and market participant expectations, both on consolidated asset and security specific levels. Significant price inflation between any round j relative to the immediately prior round $j-1$, combined with issuance of a relative small FD equity stake during the j round, leads to substantial AVD_j, which become even more significant if strong investor friendly contracts are existent, consistent with Gornall and Strebulaev (2020). Those levels of reported AVD simply underscore modeling limitations of OPM and increased beta to select exogenous assumptions, increasing the probability of generating abnormal risk-neutral results that fail to capture investor consensus and cumulative performance attributes. Common stock pool percentage has a negative impact in the observed LPY due to incremental dilution, also leading to higher deviation of EV_N relative to $PoMV_N$ in cases of higher founders equity concentration.

Neither average financing time horizon nor cumulative number of financing rounds bear any meaningful impact on the analyzed investor metrics given the reliance on a forward looking asset pricing model and the calibration approach on the indicated OIP_N that reflects cumulative asset price performance characteristics. Similarly, the average firm value increase, calculated as the percentage increase (or decrease) between the $PrMV_j$ relative to the $PoMV_{j-1}$ has a less significant role in driving asset pricing disparity; The calibration procedure to last transaction deal characteristics and the prevailing power of the last financing round reflected in the DS_N relative to $PoMV_N$ alleviates any meaningful incremental pricing pressure.

While the impact of each analyzed independent variable is different for each contracting group, the impact of the aforementioned parameters to each contract type is monotonic, highlighting that risk-adjustment is required regardless of contract design and asset pricing performance embedded in contract risk signaling.

5.4. Robustness

In this section, we address any concerns of sample, subsample or assumptions bias by performing various sensitivities on deal characteristics, contracting properties and model parameters, as presented in Table 3. We document that our analysis is robust across all sensitized groups of variables.

Deal characteristics: To mitigate potential errors or irregularities related to deal characteristics, we sensitize the (i) assumed equity pool of founders implied by the latest PoMV (1/2x-2x), (ii) the OIP of the last preferred stock (1/2x-2x), (iii) the option pool available to employees (5%-15%), (iv) the strike price of options issued to employees (30%-70% discount on a marketable basis relative to last preferred OIP) (v) DLOM applicable to common stock for 409(a) purposes (strike price for past options). All variables yield risk-neutral indications aligned with our organic expectations. Increased founders equity pool, employee pool or last preferred stock OIP leads to higher AVD with lower impact on the other key investor metrics considering proper calibration during last round. Higher embedded discount on employee options either in the form of direct haircut in implied marketable value or due to enhanced DLOM is positively correlated with greater deviation of market participant assumptions relative to risk-neutral indications, which is reflected on both AVD and SVD metrics with limited impact on investor yield and conversion outcomes considering the employees' minority interest.

Investor rights: We also sensitize key investor rights related to either the downside coverage or upside participation. We investigate the impact of (i) cash dividend rights of 6.0%-8.0% assumed range across all preferred stock issuances, (ii) LP multiple between 1.25x-1.5x across all preferred stock classes, (iii) greater upside participation in the form of attached 1.25x-1.5x CR, and (iv) enhanced anti-dilution protection in the form of full-ratchet economic rights (CP of old preferred stock is adjusted to the lowest conversion price of subsequent preferred stock classes issued in down-rounds). We observe a monotonic impact across all value related investor metrics (AVD, SVD, DP) regardless of deal properties or model parameters. Stronger LP rights are positively correlated with increased valuation delta between investors and founders, but also with a higher delta among early vs. late preferred stock investors, especially in the case of high LP multiples attached to preferred stock classes with different seniority. Conversion rights bear similar impact across the full capital structure regardless of deal properties and are also positively correlated with with valuation heterogeneity between investors vs. appraisers as well as relative value differential between founders and investors. On the other hand, adjustment of the attached anti-dilution mechanism does not have a material impact in observed risk-neutral indications considering the probabilistic assessment of high exit value outcomes.

Contracting types: We also investigate the impact of the analyzed types of VC contracts into asset pricing robustness. We assume that all recorded deals for the full VC sample are either (i) convertible, (ii) participating with no cap, (iii) participating with 3.0x cap, (iv) senior or (iv) pari-passu. Regardless of the level of risk-adjustment assumed by the introduced option pricing assumptions, incorporation of founder friendly contracts leads to lower consolidated asset value deltas and security specific value differential across the full capital structure with a converging value pattern between old investors low OIP preferred stock holdings with founders common stock. The implied LPYs and DPs suggest different level of risk adjustment consideration for proper risk reconciliation, as suggested in Section 5.1. We also observe that the incorporation of a cap condition to participating preferred stock classes, does not lead to any material adjustment into risk-neutral properties given the implied CPR of a liquidity outcome higher than the stated capital return condition.

Option pricing assumptions: Finally, we investigate the impact of principal option pricing assumptions in asset pricing heterogeneity. We have already addressed the impact of volatility and holding period in analyzed risk and return metrics in prior sections, but we also document the impact on early preferred stock classes in this section. More specifically, we sensitize the impact of (i) investment horizon assuming 1-10 years, (ii) equity volatility of 30%-150% and (iii) risk-free rate of 1%-5%. Our analysis so far has clearly illustrated that both expected exit term and volatility are leading factors driving proper risk adjustment via calibration of LPY to standard levels of market participant assumptions. Increased optionality benefits founders, employees, and early preferred investors regardless of growth stage, financing activity, equity concentration, and level of downside coverage. While increased volatility and term better reconcile VC properties by generating high exit value outcomes with a lower probabilistic assessment, increased risk-free rate growth assumptions are typically positive (negative) correlated with conversion probabilities across the full capital structure (value differential between investors and founders). Increased assumed asset growth rates harmonizes value attribution between under-performing and over-performing scenarios, minimizes valuation gap of successive preferred stock classes and enhances robustness of implied risk-neutral yield indications, especially when backed up by proper volatility and term risk adjustment.

The consolidated range of variables sensitized clearly illustrates that risk adjustment is needed across the full spectrum of VC universe regardless of deal properties and contracting characteristics, and that model parameters should be carefully selected to achieve optimal model behavior.

6. Implications for practice

Our analysis has clearly illustrated that traditional option pricing approaches, might be subject to significant mispricing relative to default market participant expectations. Risk-adjusted assumptions could enhance asset pricing robustness and should be carefully evaluated based on VC contracting properties, business stage, and asset price performance. Proper risk adjustment of VC valuations has significant financial, tax, and deal implications.

The level of risk-adjustment is a variable dynamic function of contracting structures, deal characteristics, cumulative firm asset performance, investor preferences, and access to financial information for portfolio companies, consistent with Sorensen et al. (2014). AVD, LPY and DP metrics are key variables determining valuation robustness, while equity volatility and holding period along with last financing round DS are leading parameters determining asset pricing modeling behavior. Optimization of derived LPY metrics in line with default VC private credit expectations, leads to more normal value attribution between investors, founders, and employees, and mitigates the impact of structural skewed modeling behavior of OPM in the favor of investor-friendly contracts with substantial downside coverage. Proper LPY or DP goal-seek also leads to better probabilistic assessment of high exit value outcome scenarios and better risk sharing attributes across the full capital structure, reducing security specific deviation between both early vs. late stage investors, as well as between investors and founders.

Contract signaling is a critical component of asset pricing optimization and risk-adjusted procedures that has not been typically given consideration in the context of VC OPM valuations. Under the lens of traditional finance theory, sophisticated investors leverage contract design to properly balance idiosyncratic risk with target ROE and expected payoff characteristics. A value or risk attribution analysis on the impact of strong investors rights relative to default VC contracts, could establish an LPY benchmark that could help minimize the diversifiable modeling risk related to the VC valuations. Further adjustments that consider both qualitative parameters (related to both underlying portfolio companies, securities or VCs) and quantitative factors related to portfolio performance per contracting type, successful exit probabilities, risk premiums, and opportunity cost related to alternative investments, could provide a more robust evaluation framework both in terms of parameter selection as well as output robustness.

Volatility selection is associated with a substantial level of subjectivity and potential asset pricing heterogeneity. The default approach of appraisers relying on a GPC selection and quantifying a selection based on a relative size and risk evaluation for the underlying VC-backed company is inherently exposed to different levels of risk with significant value implications. This approach resonates better with standard tools used by market participants for the determination of consolidated value and investment return metrics as noted by Gompers et al. (2016) and Gompers et al. (2020). However, different sets of GPC selections, reliance on non-uniform descriptive statistics based on fundamentally divergent views on perceived non-systematic risk, and lack of comprehensive research quantifying asset volatility premiums between public vs. private companies, high growth vs. low growth or distressed assets (as well as more specific analysis per business stage, sector, etc.), are fundamental reasons leading to an increased diversifiable risk in the case of volatility selection. A consideration of the equity beta volatility method utilized in this paper as a benchmark floor for standard deviation of assets, mitigates the impact of exogenous parameters with robustness diminishing characteristics and harmonized risk incorporation parameters. The selected volatility should be a function of systematic risk, idiosyncratic risk assumptions which also embed critical risk and return components signaled by contract design and VC investment preferences, as well as modeling construction properties to achieve optimal risk-adjusted probabilistic exit outcome and value behavior. Optimal volatility levels should be selected based on the evaluation of all the analyzed risk-neutral derived risk and return metrics referenced in this paper to minimize error pricing likelihood.

Similarly, selection of investment horizon assumptions should consider (i) investor preferences, (ii) company-specific information, (iii) standard market participants assumptions for companies of similar risk and stage, as well as (iv) derived modeling risk and return properties to ensure proper reconciliation of VC characteristics. Careful consideration should always be given to the business stage of the underlying VC-backed company. Although increased option pricing assumptions for a late-stage VC venture might lead to optimal risk attribution to the full capital structure, similar exogenous assumptions applicable to a risky early-stage business might lead to improper balancing of founders' shares risk properties and unrealistic exit value outlook assessment.

Sizable transactions in the secondary market on old or junior preferred stock classes or common stock that provide credible pricing information, should also be carefully considered in optimizing selection of option pricing assumptions and asset pricing robustness. A double calibration could be performed (i) value of the preferred security N is equal to OIP and (ii) the value of the security j with $j \neq N$, is equal to the price in the secondary market) solving for the levels of EV_N and equity volatility σ that calibrate both parameters to the indicated values. If convergence cannot be achieved even by altering the investment holding period assumption, a switch to hybrid models is required with a higher level of flexibility in the relative value properties between old vs. new investors or investors vs. founders (i.e., optimal selection of IPO weight q in addition to option pricing assumptions or specific IPO exit value outcomes in other forms of hybrid methods[22]).

Finally, method selection is a critical component of asset pricing and should be always evaluated based on a comprehensive overview of all related idiosyncratic business characteristics, investor risk tolerance assumptions, market participants benchmarks, and structural limitations of each approach. Hybrid methods might mitigate more appropriately the impact of significant downside coverage protection rights or better harmonize value attribution characteristics across equity holders in late-stage VC ventures with successful financing history, but their added value on early-stage ventures with significant uncertainty about the ability to continue on a going concern basis is questionable. Consideration of contract signaling, business stage, and market participants yield expectations could minimize errors related to method selection.

[22]Refers to reliance on probability-weighted expected return method (PWERM), which is typically incorporated when specific pre-money IPO valuation indications are available.

7. Conclusion

Our paper investigates pricing heterogeneity between traditional asset pricing models, typically relied upon appraisers, relative to PoMV indications typically leveraged by VCs. Based on an option pricing analysis of 2,056 US VC-backed companies with 9,188 deals, we provide robust evidence that absence of proper risk-adjustment of option pricing assumptions leads to improper risk balance across the full capital structure and lack of reconciliation of key VC properties. Our analysis suggests that equity volatility and holding period are key parameters optimizing investor risk and return metrics, and minimizing valuation heterogeneity regardless of deal or contracting characteristics. We provide a security-return designed evaluation framework leading to robust value attribution between investors, founders and employees and harmonized risk bifurcation across securities with asymmetric payoff properties. We leverage structural market signals of VC contracts in optimizing endogenous derivation of investor risk premiums and increasing valuation robustness across all analyzed risk and return variables. We suggest that standard deviation of assets should be determined endogenously based on contract risk signaling and default investor return expectations. Determination of risk-adjusted option pricing parameters is a dynamic optimization process considering contracting rights, deal characteristics, market participants organic expectations, and modeling properties. Our results are robust and scalable to the broader VC universe with significant financial reporting, tax and deal implications.

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Figure 1: VC deals history

This figure shows the evolution of Venture Capital (VC) deals, in terms of deal-count and size, in the US from 2000 to 2024. The left axis represents the total value of VC deals in billions of U.S. dollars, while the right axis indicates the number of VC deals completed for a given year. The sample includes full transactions and completed deals across all VC stages, sourced from PitchBook Data, Inc.

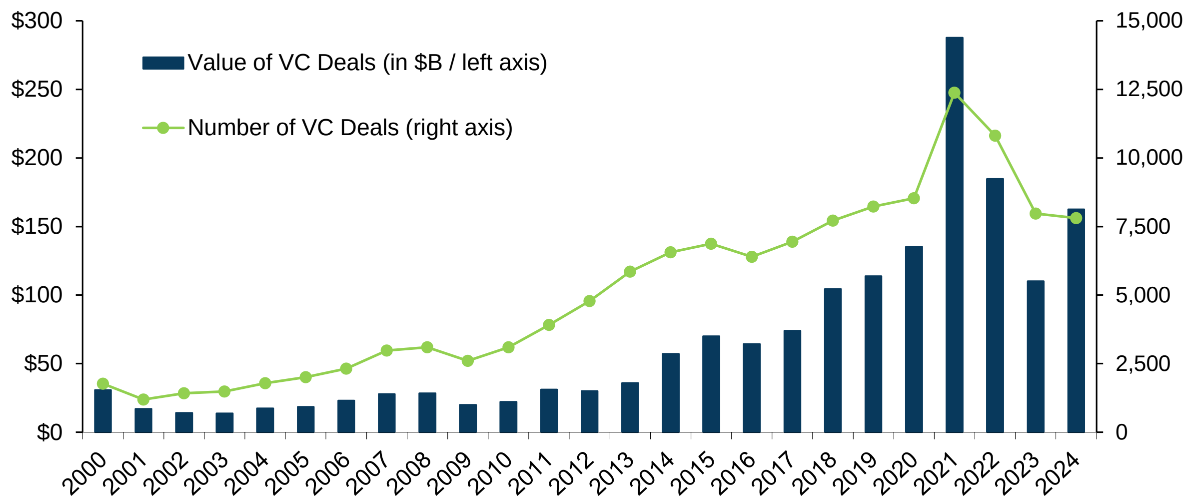


Figure 2: Graphical illustration of participation ratio functions

This figure shows the participation ratio function of the common stock, Series A, and Series B preferred Stock considered in our simplified hypothetical example. The term B_i indicates the breakpoint equity value (EV) threshold at which at least one allocation ratio changes, whereas ω_{ji} denotes the allocation ratio of the j-th security applicable at the i-th breakpoint. For this example, we assume that the number of Series A, Series B and common stock is equal, and further, we assume that the original issue price (OIP) of Series B is twice the Series A OIP. The conversion price (CP) of each preferred stock class matches the OIP, assuming a liquidation preference (LP) multiple of 1.0x and no attached dividend rights.

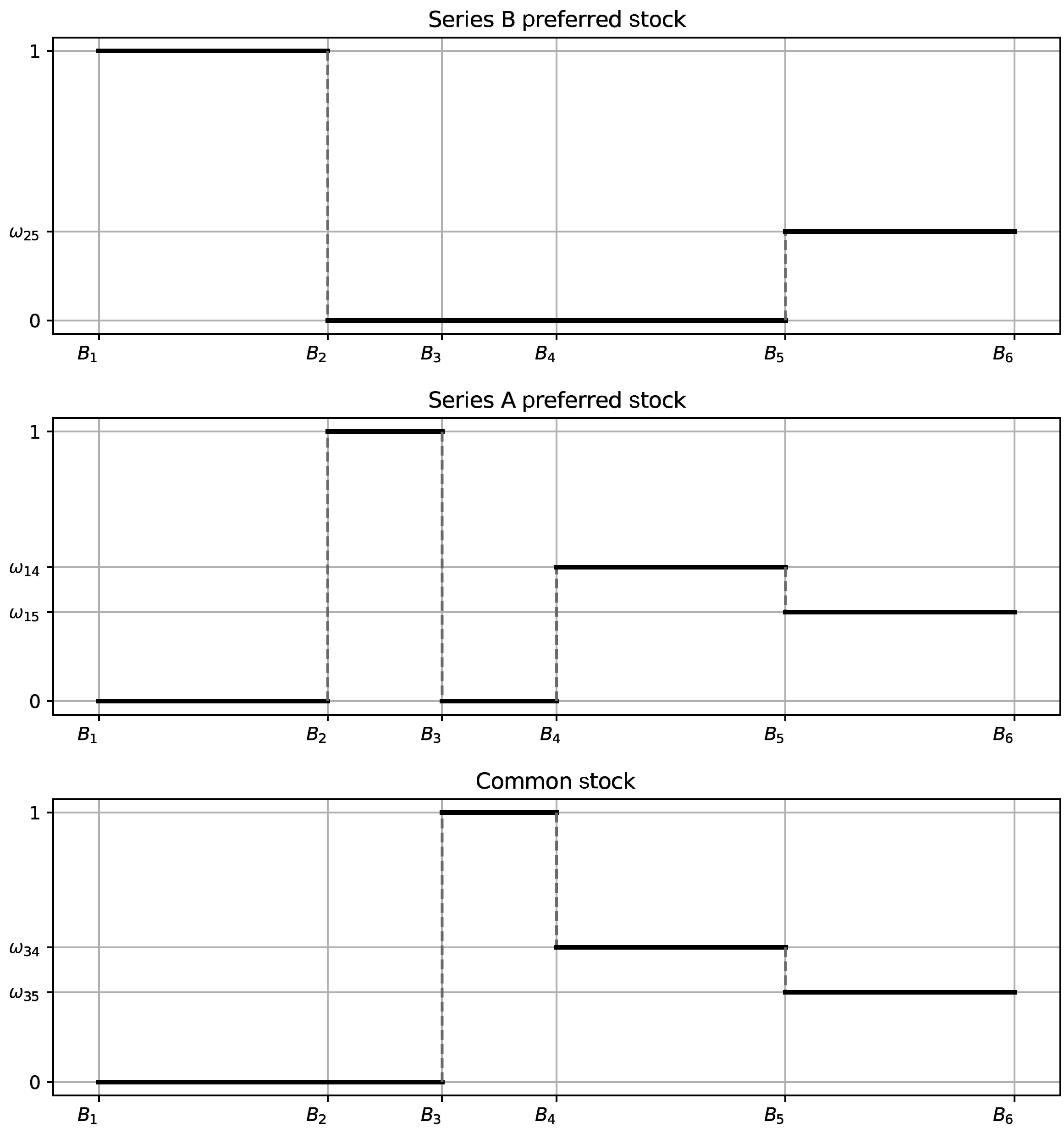


Figure 3: Risk and return characteristics of VC contracts

This figure shows the sensitivity of the median implied valuation risk and return metrics to changes in investment horizon (T) and equity volatility (σ), for two groups of contracting structures (convertible versus participating and senior versus pari-passu). Subscript N (C) denotes the last preferred stock (common stock). LPY: liquidation preference yield, DP: downside protection value relative to the total security value, CPR: conversion probability, AVD: asset value delta of implied equity value (EV) relative to the post-money valuation (PoMV), SVD: value delta of a specified security relative to the last preferred stock.

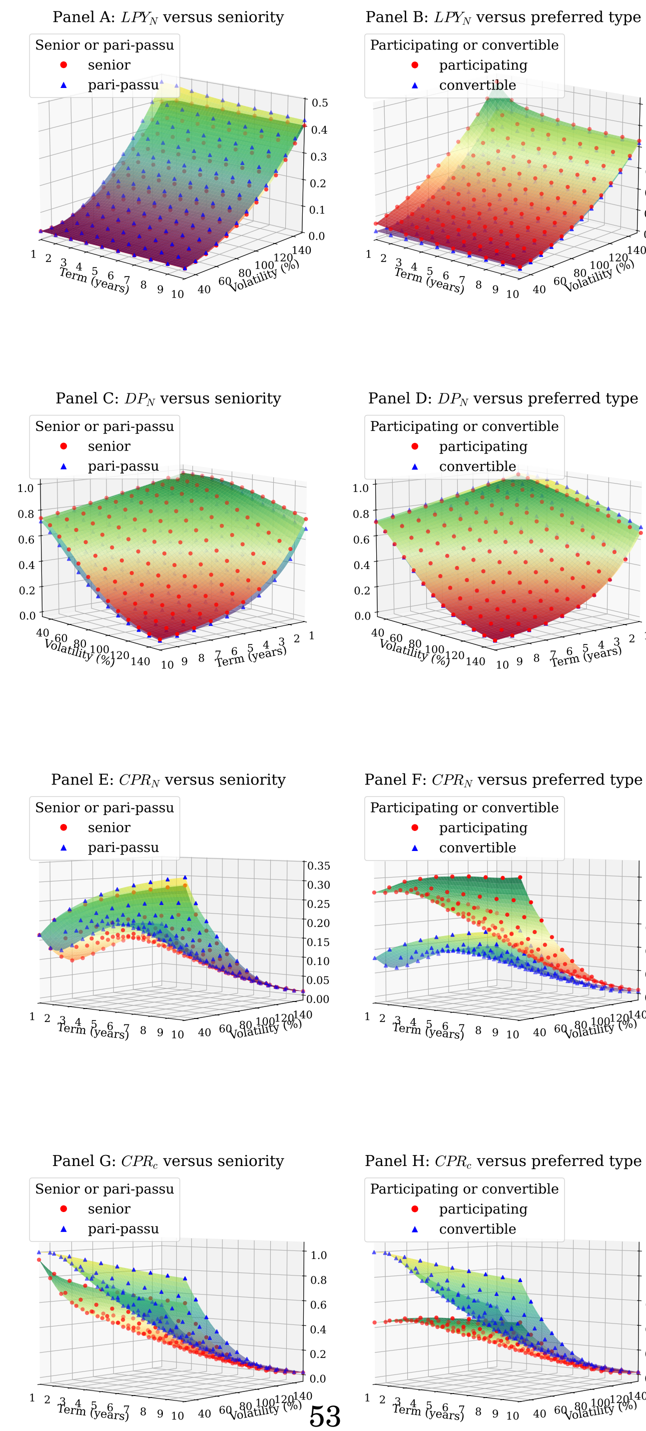


Figure 3: Risk and return characteristics of VC contracts (continued)

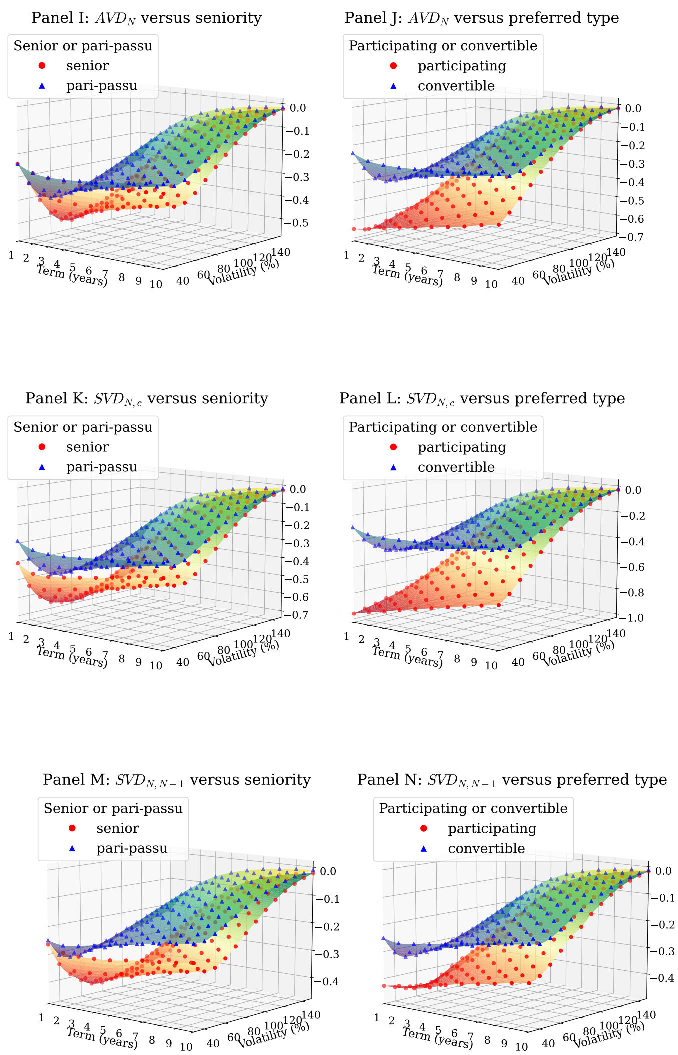


Figure 4: Reconciling VC properties

This figure shows the sample distribution for each analyzed metric depending on changes in investment horizon (T) and equity volatility (σ). Subscript N [N-1] (C) denotes the last preferred stock [second to last preferred stock] (common stock). LPY: liquidation preference yield, DP: downside protection value relative to the total security value, CPR: conversion probability, AVD: asset value delta of implied equity value (EV) relative to the post-money valuation (PoMV), SVD: value delta of a specified security relative to the last preferred stock.

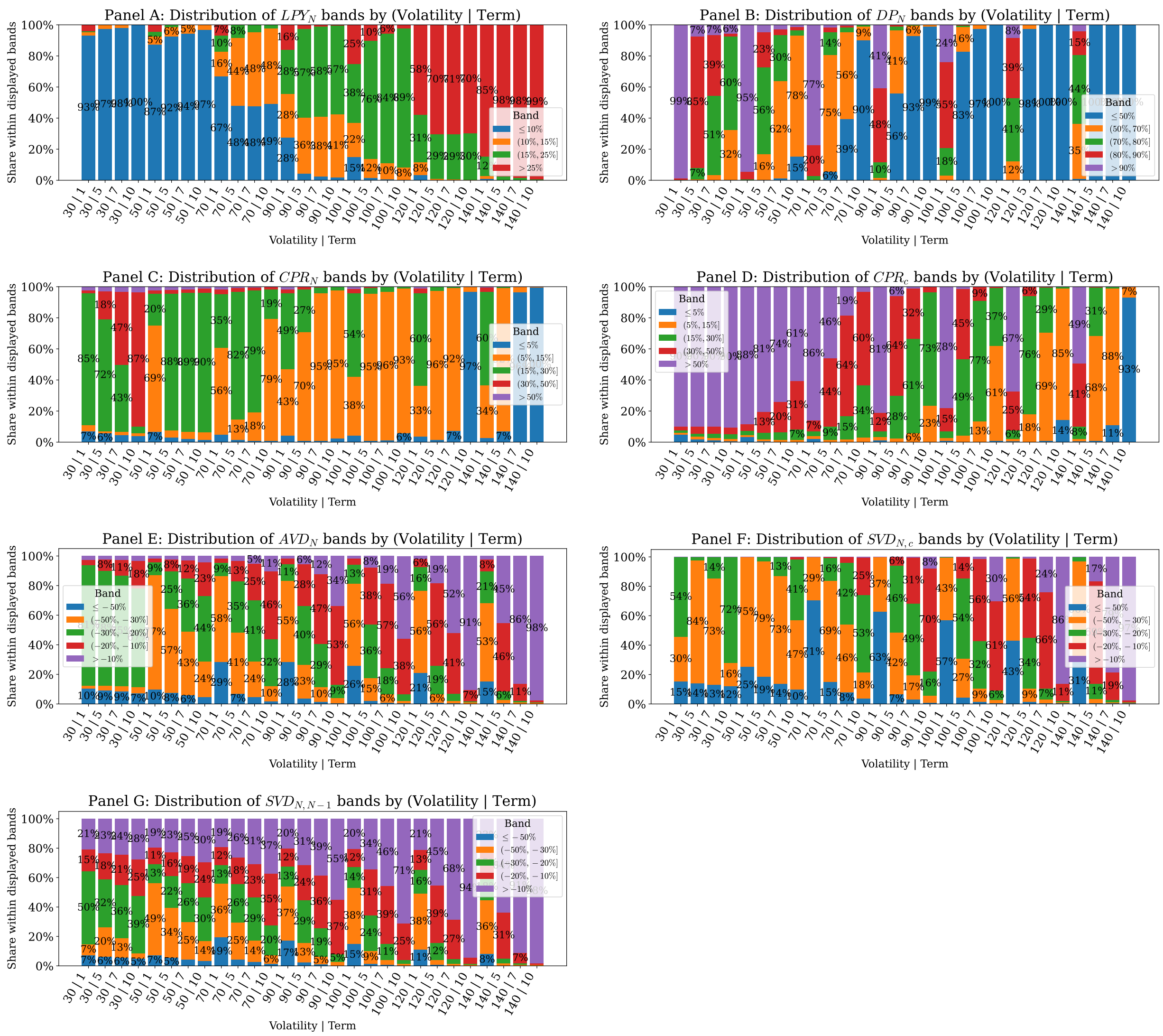


Figure 5: Contracts, growth stage and founders value

This figure shows the evolution of founders value based on various parameters. Panel A illustrates value across all four contracting groups based on the full spectrum of option pricing assumptions (investment horizon (T) and equity volatility (σ)). Panel B summarizes the impact of growth stage in the value attributable per contract type and in totality based on various option pricing assumptions. Panel C describes in more detail the impact of subsequent financing rounds in relative value allocation between investors and founders. Subscript N (C) denotes the last preferred stock (common stock). LPY: liquidation preference yield, DP: downside protection value relative to the total security value, SVD: value delta of a specified security relative to the last preferred stock.

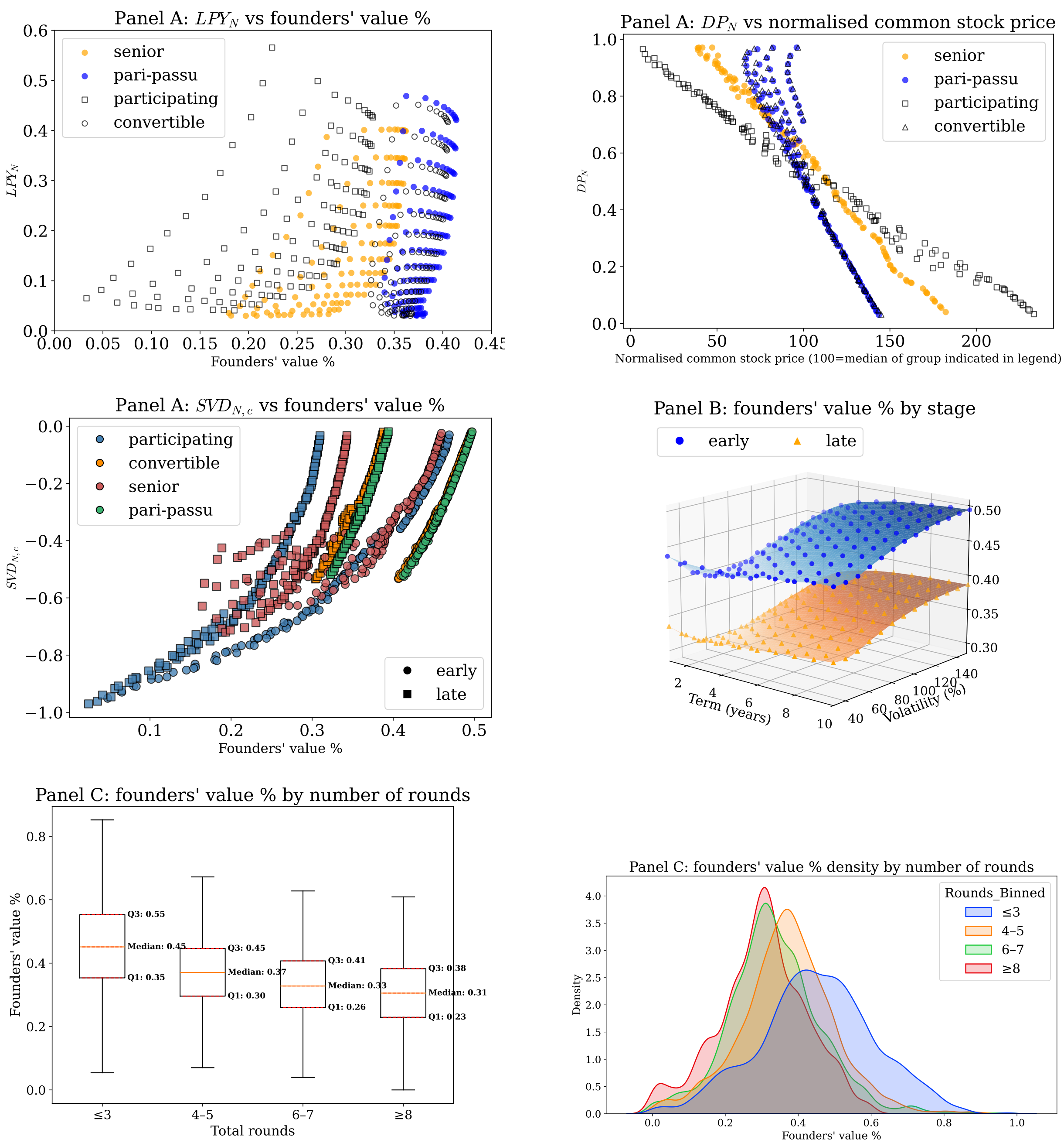
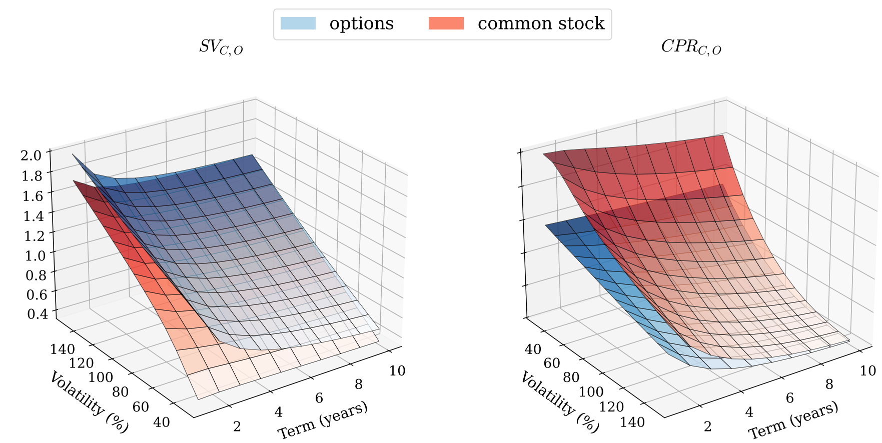


Figure 6: Contracts and stock-based compensation

This figure shows the impact of Venture Capital (VC) contracts and model parameters into stock-based compensation. Panel A describes how option pricing parameters (investment horizon (T) and equity volatility (σ)) affect the security specific volatility and in-the-moneyness probability for common stock and options. Panel B illustrates the relationship between key investor metrics relative to value differential between employee options versus last preferred stock pricing for each contracting group analyzed. Subscript N (C) [O] denotes the last preferred stock (common stock) [options]. SV: security volatility, CPR: conversion probability, LPY: liquidation preference yield, AVD: asset value delta of implied equity value (EV) relative to the post-money valuation (PoMV), SVD: value delta of a specified security relative to the last preferred stock.

Panel A



Panel B

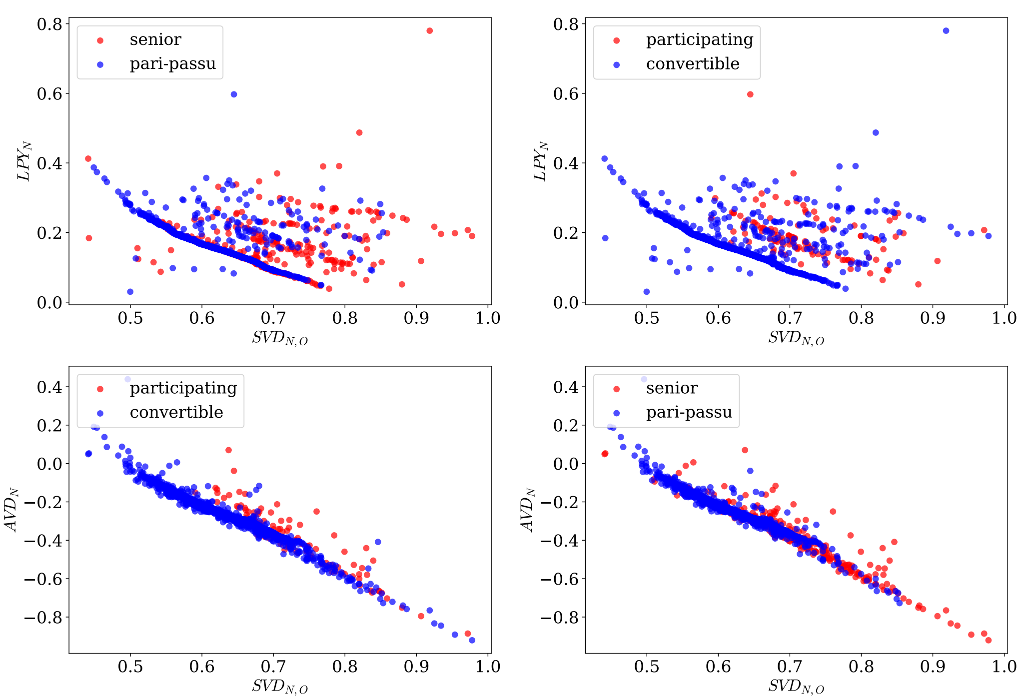


Figure 7: Contracts and risk signaling

This figure shows the output of our with/without analysis illustrating the impact of Venture Capital (VC) contracts on the implied liquidation preference yield (LPY) considering the full spectrum of option pricing parameters (investment horizon (T) and equity volatility (σ)). By amending the properties of convertible (pari-passu) to participating (senior), all else equal, we investigate if derived risk adjusted valuation indications properly reflect the amendment in risk properties signaled by the VC contracts. Panel A (B) summarizes our findings for the comparison between convertible vs. participating (pari-passu vs. senior). Subscript N denotes the last preferred stock.

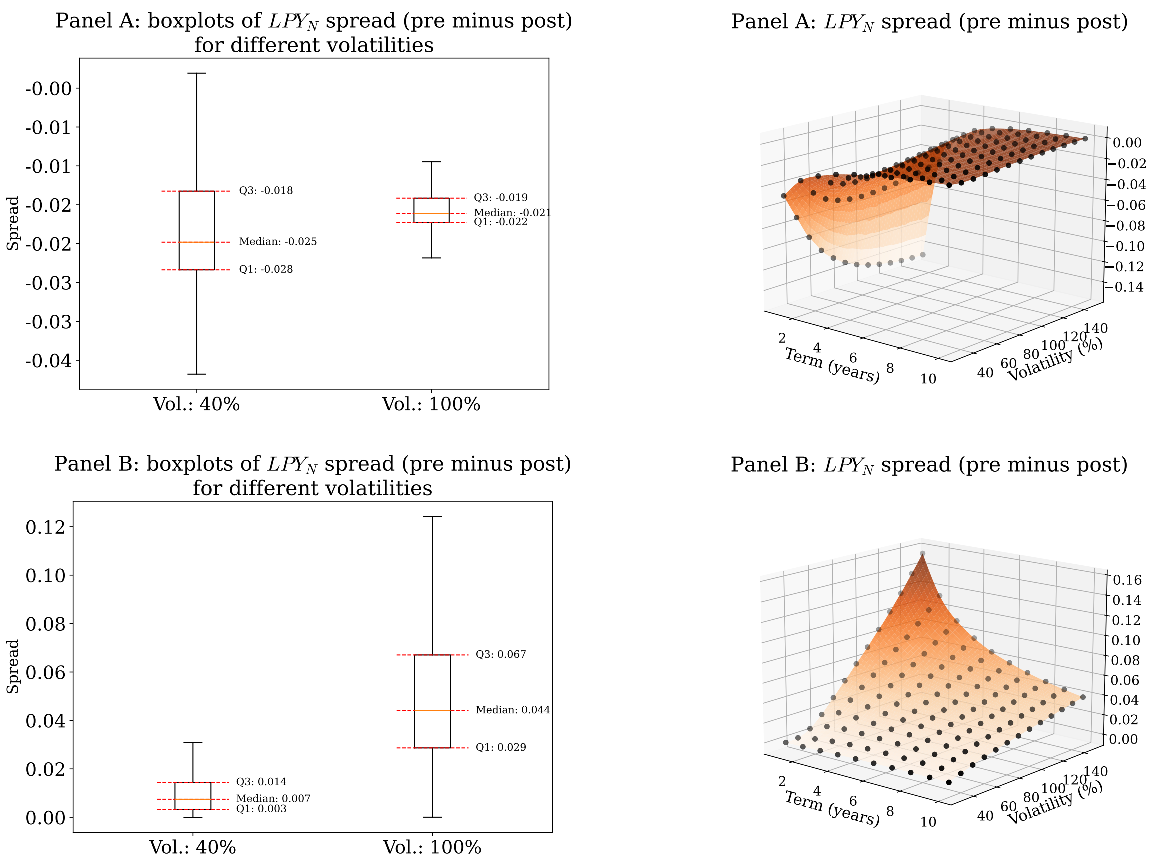


Figure 8: Contract seniority and volatility spread

This figure shows the spread (ds) of the implied equity volatility (σ_s) of senior preferred Venture Capital (VC) contracts relative to the equity volatility of default pari-passu contracts (σ_{pp}), after proper incorporation of contract risk signaling. We apply the with/without framework described in Section 5.1 to the subsample of VC-backed companies that issued a senior preferred stock during the last financing round. The liquidation preference yield (LPY) of the last preferred stock N is calibrated to the return benchmark implied by the same deal characteristics and option pricing inputs, assuming that the new security was instead issued as a default pari-passu VC contract. The spread is calculated for the full set of option pricing assumptions (investment horizon (T) and equity volatility (σ)). In this case σ=σ_{pp} and ds= σ_s - σ_{pp}.

Implied volatility spread for senior preferred contracts

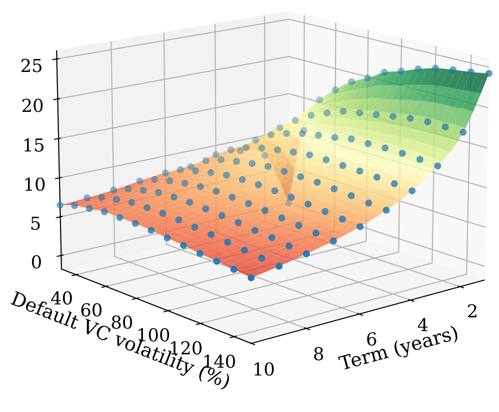


Figure 9: Volatility, preferred yield and contracts

This figure shows the impact that risk-adjustment in the form of optimization of liquidation preference yield (LPY) has in the implied equity volatility (σ)) of the full sample as well as per Venture Capital (VC) contract. Panel A summarizes the impact for senior vs. pari-passu contracts. Panel B summarizes the impact for convertible vs. participating contracts. In panel B, the dotted line with the description *participating + 500 bps (350 bps)*, assumes that there is a constant spread between between convertible and participating structures of 5% (3.5%), and the Y axis reflects the target LPY return for convertible structures. Subscript N denotes the last preferred stock, bps:basis points

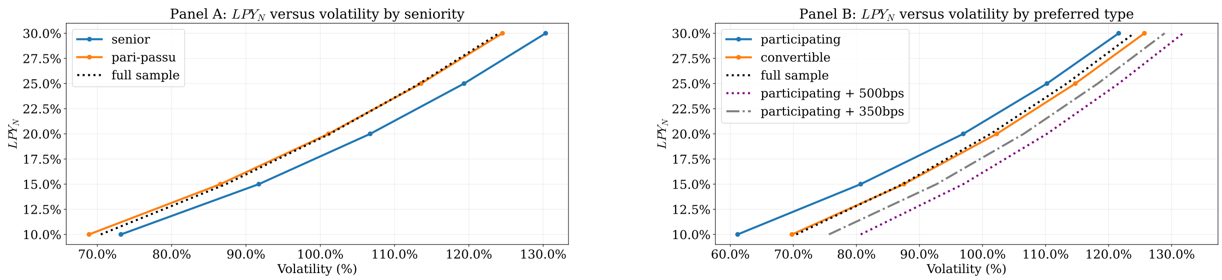


Table 1: Risk-adjusted VC valuations

The table summarizes key value metrics based on risk adjustment of different parameters. The Base case illustrates the median derived metrics of the full sample based on a 40.0% equity volatility and a 3-year holding period. All the contemplated risk-adjustment scenarios leverage a 5-year holding period and solve for an implied equity volatility, unless calibration cannot be reached. In those cases, an extension of applicable holding period and increase of volatility is triggered until the calibration of the value of the last preferred stock to its original issue price (OIP) and the stated level of optimized parameter is reached. Panel A includes the valuation output based on optimization of derived liquidation preference yield (LPY) in the range of 10.0% to 25.0%. Panel B includes an optimization based on derivation of the equity volatility using market participants return on equity (ROE) build-up according to the formula described in Section 2.4. Panel C follows similar rationale as Panel B but solving for an individual security volatility instead of overall equity volatility. Derivation of security specific volatility is provided in Appendix A. Panel D summarizes valuation results based on differentiation of risk profile of early vs. late stage investments by assigning a fixed spread in the implied yield between 5% to 10%. Panel E applies similar rationale to different contracting groups by accounting for a constant spread differential of 5% to 10% between investor friendly and founder friendly contracts. Panel F summarizes the valuation results of a hybrid approach including separate treatment of an initial public offering (IPO) vs. a sale scenario and concludes on weighted average value indications. *N*: last preferred stock, *N-1*: second to last preferred stock, *1*: first issued preferred stock, *C*: common stock, AVD: asset value delta of implied equity value (EV) relative to the post-money valuation (PoMV), SVD: value delta of a specified security relative to the last preferred stock, DP: downside protection value relative to the total security value, CPR: conversion probability, n/a: not applicable.

Scenarios	AVD_N	$SVD_{N,N-1}$	$SVD_{N,1}$	$SVD_{N,C}$	LPY_N	LPY_{N-1}	LPY_1	DP_N	DP_{N-1}	DP_1	CPR_N	CPR_{N-1}	CPR_1	CPR_C
Base case	-35.7%	-28.7%	-41.1%	-42.1%	3.9%	4.2%	4.5%	89.8%	68.6%	12.6%	19.9%	44.3%	80.2%	86.9%
Panel A: Preferred yield optimization														
10.00% LPY	-35.4%	-27.1%	-41.3%	-43.8%	10.0%	10.0%	10.0%	75.1%	54.6%	9.6%	18.5%	31.6%	55.5%	61.6%
15.0% LPY	-31.8%	-24.2%	-37.0%	-39.0%	15.0%	15.0%	15.0%	65.8%	45.3%	7.7%	17.0%	27.0%	45.4%	50.5%
20.0% LPY	-28.3%	-21.4%	-33.0%	-35.1%	20.0%	20.0%	20.0%	57.9%	38.1%	6.1%	15.4%	23.6%	38.4%	42.6%
25.0% LPY	-25.3%	-19.0%	-29.4%	-31.4%	25.0%	25.0%	25.0%	51.2%	32.6%	5.0%	13.8%	20.7%	33.0%	36.6%
Panel B: Beta equity volatility														
30.0% ROE (85.1% σ)	-32.5%	-24.5%	-37.7%	-40.8%	14.3%	15.8%	16.7%	68.0%	46.3%	7.7%	17.3%	27.2%	44.4%	49.6%
35.0% ROE (100.8% σ)	-28.7%	-21.4%	-33.2%	-36.1%	19.8%	21.8%	22.9%	59.1%	38.4%	6.1%	15.5%	23.1%	36.9%	40.9%
40.0% ROE (116.6% σ)	-24.8%	-18.3%	-28.5%	-31.2%	26.5%	28.8%	30.1%	50.3%	31.3%	4.8%	13.4%	19.4%	30.3%	33.5%
Panel C: Beta security volatility														
30.0% ROE (85.1% σ_j)	-26.1%	-19.5%	-30.4%	-32.7%	23.7%	24.3%	24.7%	53.3%	33.6%	5.2%	14.3%	21.3%	33.6%	37.3%
35.0% ROE (100.8% σ_j)	-22.7%	-16.9%	-26.4%	-28.5%	30.0%	30.9%	31.4%	46.0%	27.9%	4.2%	12.5%	18.0%	28.0%	31.1%
40.0% ROE (116.6% σ_j)	-19.6%	-14.4%	-22.6%	-24.6%	37.3%	38.4%	39.1%	39.1%	22.8%	3.4%	10.7%	15.2%	23.1%	25.7%
Panel D: Spread vs business stage														
10.0% spread / LPY 10.0% - early	-29.0%	-27.8%	-32.3%	-36.2%	10.0%	10.0%	10.0%	62.1%	30.3%	13.7%	18.4%	35.2%	43.1%	51.7%
10.0% spread / LPY 20.0% - late	-20.0%	-12.8%	-23.6%	-24.7%	20.0%	20.0%	20.0%	40.2%	26.8%	2.5%	11.8%	15.9%	27.7%	29.5%
10.0% spread / LPY 15.0% - early	-23.9%	-22.5%	-26.5%	-29.9%	15.0%	15.0%	15.0%	49.7%	22.2%	9.7%	15.0%	26.7%	32.4%	38.7%
10.0% spread / LPY 25.0% - late	-16.5%	-10.4%	-19.5%	-20.4%	25.0%	25.0%	25.0%	32.8%	21.0%	1.9%	9.6%	12.8%	22.0%	23.4%
Panel E: Spread vs contract type														
5.0% spread / LPY 10.0% - convertible	-29.0%	-22.0%	-33.9%	-35.9%	10.0%	10.0%	10.0%	62.1%	41.7%	6.6%	17.8%	28.2%	46.5%	51.4%
5.0% spread / LPY 15.0% - participating	-37.3%	-28.8%	-42.9%	-49.7%	15.0%	24.1%	28.0%	49.7%	36.0%	15.8%	29.2%	27.8%	28.4%	29.3%
5.0% spread / LPY 15.0% - convertible	-23.9%	-17.9%	-27.9%	-29.7%	15.0%	15.0%	15.0%	49.7%	31.3%	4.7%	14.5%	21.7%	34.9%	38.4%
5.0% spread / LPY 20.0% - participating	-30.2%	-23.5%	-35.0%	-40.2%	20.0%	30.5%	34.5%	40.2%	26.6%	9.6%	23.4%	22.7%	22.7%	23.5%
no spread / LPY 10.0% - pari-passu	-28.2%	-19.6%	-33.0%	-35.2%	10.0%	10.0%	10.0%	62.1%	41.7%	6.6%	18.7%	29.7%	48.0%	52.0%
no spread / LPY 10.0% - senior	-36.7%	-33.1%	-42.1%	-44.6%	10.0%	21.0%	24.4%	62.1%	43.2%	9.8%	14.6%	19.5%	30.1%	34.4%
5.0% spread / LPY 15.0% - senior	-30.0%	-27.5%	-33.9%	-36.7%	15.0%	28.1%	31.3%	49.7%	30.0%	6.0%	12.1%	16.2%	23.2%	26.3%
no spread / LPY 15.0% - pari-passu	-23.2%	-15.8%	-27.3%	-29.2%	15.0%	15.0%	15.0%	49.7%	31.8%	4.7%	15.2%	23.0%	35.9%	38.9%
no spread / LPY 20.0% pari-passu	-19.1%	-12.8%	-22.4%	-24.1%	20.0%	20.0%	20.0%	40.2%	24.8%	3.5%	12.3%	18.2%	27.9%	30.2%
no spread / LPY 20.0% senior	-24.6%	-22.7%	-27.6%	-29.6%	20.0%	34.6%	37.9%	40.2%	21.7%	4.0%	9.8%	13.3%	18.6%	20.6%
Panel F: Hybrid approach														
25.0% IPO weight	-15.6%	-11.4%	-17.8%	-19.6%	n/a	n/a	n/a	n/a	n/a	n/a	34.3%	38.0%	45.0%	47.0%
50.0% IPO weight	-10.4%	-7.6%	-11.9%	-13.1%	n/a	n/a	n/a	n/a	n/a	n/a	56.2%	58.7%	63.3%	64.7%
75.0% IPO weight	-5.2%	-3.8%	-5.9%	-6.5%	n/a	n/a	n/a	n/a	n/a	n/a	78.1%	79.4%	81.7%	82.3%

Table 2: Asset pricing robustness and key valuation factors

This table presents the results of Random Effects regressions of key investor return metrics relative to important deal characteristics, performance variables and option pricing assumptions, each scaled to have zero mean and unit variance. Liquidation preference yield (LPY) , downside protection (DP) and asset value delta (AVD) are the dependent variables. Standard error and p-value is also presented for each regression analysis. Mean financing time refers to then average timing between successive financing rounds based on the cumulative deal history of each company. Mean firm value increase refers to the average increase between financing rounds measured as the percentage increase or decrease of the pre-money valuation (PrMV) of a preferred security j relative to the post-money valuation (PoMV) of the immediately prior round $j-1$. Deal size refers to the amount raised in connection with the issuance of the last preferred stock N. Common pool refers to equity percentage of the common stock relative to the fully-diluted (FD) number of shares of each company, assuming conversion or exercise of all issued and outstanding classes. The R squared (within) addresses the variation explained by changes related to various optionality scenarios for each asset (the fluctuations of investment horizon T and equity volatility σ). The R squared (between) measures the fit of the model for the remaining company-fixed explanatory variables.

	LPY_N	Std.Err.	P-Vl.	DP_N	Std.Err.	P-Vl.	AVD_N	Std.Err.	P-Vl.
Constant	0.193	0.001	0.000	0.521	0.001	0.000	-0.242	0.002	0.000
Investment horizon T	-0.009	0.000	0.000	-0.169	0.000	0.000	0.076	0.000	0.000
Equity volatility σ	0.124	0.000	0.000	-0.201	0.000	0.000	0.068	0.000	0.000
Mean financing time	0.001	0.001	0.324	0.006	0.001	0.000	-0.013	0.002	0.000
Number of financing rounds	-0.001	0.001	0.281	0.004	0.002	0.004	-0.000	0.003	0.962
Deal size / PoMV	0.023	0.001	0.000	-0.031	0.001	0.000	0.052	0.003	0.000
Mean firm value increase	-0.006	0.001	0.000	0.005	0.001	0.000	-0.006	0.002	0.002
Common pool	-0.011	0.001	0.000	0.011	0.002	0.000	-0.009	0.003	0.000
R-Squared (within)	82.37%			93.07%			68.61%		
R-Squared (between)	37.31%			31.93%			28.60%		

Table 3: Robustness to different deal, investor and capital structure assumptions

The table shows the sensitivity of key investor metrics to a range of parameters. Panel A contemplates a sensitivity around select deal characteristics. *1/2x Common stock* considers a scenario in which the number of common stock is reduced by half, whereas *2x Common stock* assumes that the common stock share-count is double. *1/2x* OIP_N assumes that the original issue price (OIP) of last round N is half, while *2x* OIP_N assumes a double OIP for the last preferred security. *5% Options* (*15% Options*) assumes an effective 5% (15%) fully-diluted (FD) equity ownership for options, respectively. *30%* K_O *discount* (*70%* K_O *discount*) considers a discount of 30% (70%) for the marketable value of past options, while *10%* $DLOM_C$ (*20%* $DLOM_C$) assumes a 10% (20%) applicable discount for lack of marketability (DLOM) for past options. Panel B entails a sensitivity analysis around investor rights. *6% Pref div (cash)* (*8% Pref div (cash)*) assumes that all preferred securities across all financing rounds are entitled to a 6% (8%) cash dividend right. *1.25x LP* (*1.5x LP*) assumes that all preferred securities across all financing rounds are entitled to an 1.25x (1.5x) liquidation preference (LP) multiple. *1.25x CR* (*1.5x CR*) assumes that all preferred securities across all financing rounds are entitled to an 1.25x (1.5x) conversion ratio (CR). *Full-ratchet anti-dilution* denotes that all preferred securities are subject to full-ratchet anti-dilution instead of weighted average anti-dilution protection. Panel C summarizes a sensitivity around key contracting properties. *All convertible* (*All participating (no cap)*) [*All participating (3.0x cap)*] denotes that all preferred securities across all financing rounds are all convertible (participating without any cap) [participating with an attached 3.0x cap]. *All senior* (*All pari-passu*) denotes that all preferred stock classes across all financing rounds are senior to the prior one (pari-passu relative to the prior one). Finally, Panel D presents the results of the sensitivity analysis around option pricing assumptions. *1 year T* (*10 years T*) assume an investment horizon of 1 year (10 years) from the last financing transaction, *30%* σ (*30%* σ) denotes a sensitivity of the equity volatility based on 30% (150%) standard deviation of assets and *1% Rf* (*5% Rf*) denotes that the risk-neutral drift rate or utilized risk-free rate of return is 1% (5%).

Scenarios	AVD_N	$SVD_{N,N-1}$	$SVD_{N,1}$	$SVD_{N,C}$	LPY_N	LPY_{N-1}	LPY_1	DP_N	DP_{N-1}	DP_1	CPR_N	CPR_{N-1}	CPR_1	CPR_C
Base Case	-20.8%	-15.2%	-23.7%	-26.1%	19.3%	20.7%	21.5%	42.2%	25.2%	3.8%	12.4%	17.4%	26.6%	29.3%
Panel A: Deal characteristics														
1/2x Common stock	-17.2%	-13.5%	-21.2%	-23.3%	21.1%	22.6%	23.4%	39.2%	23.1%	3.3%	12.8%	17.5%	24.7%	26.1%
2x Common stock	-26.0%	-17.6%	-27.4%	-30.4%	17.0%	18.3%	19.0%	46.5%	28.4%	4.4%	11.8%	17.0%	29.2%	34.0%
1/2x OIP_N	-16.0%	-1.4%	-19.4%	-23.0%	21.6%	23.6%	24.8%	38.2%	38.1%	6.3%	12.5%	11.9%	21.1%	24.5%
2x OIP_N	-24.3%	-23.2%	-27.0%	-28.8%	17.8%	18.7%	19.4%	45.1%	15.%	2.1%	12.1%	22.8%	31.1%	33.2%
5% Options	-21.0%	-15.1%	-23.6%	-25.9%	19.3%	20.7%	21.5%	42.2%	25.1%	3.7%	12.5%	17.6%	26.7%	29.3%
15% Options	-21.4%	-15.0%	-23.3%	-25.6%	19.4%	20.8%	21.5%	42.1%	25.0%	3.7%	12.6%	17.9%	27.0%	29.2%
30% K_O discount	-21.1%	-15.1%	-23.5%	-25.8%	19.3%	20.7%	21.5%	42.1%	25.1%	3.7%	12.5%	17.7%	26.8%	29.2%
70% K_O discount	-21.2%	-15.0%	-23.4%	-25.8%	19.3%	20.7%	21.5%	42.1%	25.1%	3.7%	12.5%	17.8%	26.9%	29.23%
10% $DLOM_C$	-21.2%	-15.0%	-23.4%	-25.8%	19.3%	20.7%	21.51%	42.1%	25.1%	3.7%	12.6%	17.8%	26.9%	29.23%
20% $DLOM_C$	-21.2%	-15.03%	-23.6%	-25.8%	19.33%	20.7%	21.5%	42.1%	25.1%	3.7%	12.5%	17.7%	26.9%	29.2%
Panel B: Investor rights														
6% Pref div (cash)	-24.8%	-17.2%	-28.5%	-31.9%	22.7%	24.4%	25.3%	48.6%	31.9%	6.1%	9.5%	13.14%	20.5%	23.4%
8% Pref div (cash)	-26.2%	-17.6%	-30.2%	-33.8%	23.9%	25.8%	26.7%	50.6%	34.3%	7.2%	8.7%	11.9%	18.7%	21.5%
1.25x LP	-24.6%	-17.9%	-28.3%	-31.0%	21.4%	23.1%	23.9%	47.7%	29.3%	4.5%	10.1%	14.5%	22.8%	25.4%
1.5x LP	-28.0%	-20.4%	-32.3%	-35.4%	23.6%	25.3%	26.2%	52.4%	32.9%	5.2%	8.4%	12.3%	19.8%	22.3%
1.25x CR	-27.1%	-14.9%	-23.2%	-39.9%	19.9%	21.3%	22.2%	41.1%	24.6%	3.6%	12.5%	17.4%	25.8%	28.1%
1.5x CR	-31.2%	-14.4%	-22.6%	-49.4%	20.4%	21.8%	22.7%	40.2%	24.0%	3.5%	12.6%	17.5%	25.2%	27.3%
Full-ratchet anti-dilution	-21.0%	-14.4%	-22.5%	-26.1%	19.3%	20.7%	21.3%	41.9%	24.2%	3.6%	12.5%	17.7%	26.7%	29.3%
Panel C: Contracting properties														
All convertible	-20.5%	-15.1%	-23.5%	-25.8%	19.3%	20.6%	21.4%	42.3%	25.2%	3.7%	12.3%	17.0%	26.6%	29.4%
All participating (no cap)	-31.1%	-20.7%	-36.3%	-40.4%	20.5%	21.8%	22.6%	40.2%	25.4%	4.3%	27.3%	27.3%	27.3%	27.3%
All participating (3.0x cap)	-29.2%	-20.6%	-34.2%	-37.0%	20.20%	21.6%	22.4%	40.7%	25.7%	4.2%	27.8%	27.8%	27.8%	27.8%
All senior	-29.9%	-26.5%	-33.1%	-35.2%	15.8%	27.3%	33.1%	49.7%	23.5%	2.9%	11.3%	15.8%	24.6%	27.3%
All pari-passu	-18.8%	-12.0%	-21.6%	-24.4%	20.1%	20.1%	20.1%	40.5%	25.4%	4.1%	12.6%	17.7%	27.0%	29.7%
Panel D: Option pricing assumptions														
1 year T	-41.5%	-31.4%	-48.5%	-51.6%	17.9%	20.9%	22.9%	85.7%	65.4%	12.4%	16.1%	31.2%	57.6%	65.1%
10 years T	-9.3%	-6.6%	-10.3%	-11.7%	18.7%	19.5%	20.0%	18.5%	9.9%	1.4%	6.4%	8.6%	12.6%	13.9%
30% σ	-28.0%	-23.8%	-31.9%	-33.0%	3.3%	3.4%	3.5%	85.5%	62.8%	10.7%	27.4%	53.4%	87.2%	92.1%
150% σ	-8.6%	-6.0%	-9.5%	-10.9%	43.6%	45.8%	47.0%	16.7%	8.9%	1.2%	4.8%	6.5%	9.6%	10.5%
1% Rf	-22.4%	-16.4%	-25.7%	-28.3%	18.0%	19.4%	20.1%	44.7%	26.9%	4.1%	11.3%	16.1%	24.9%	27.5%
5% Rf	-19.2%	-14.1%	-21.9%	-24.1%	20.7%	22.0%	22.8%	39.8%	23.5%	3.5%	13.5%	18.8%	28.3%	31.1%

Appendix

A. Contracting rights and sample characteristics

Table 1: Economic rights of preferred stock securities

This table provides an overview of key contract terms of preferred stock classes typically observed in Venture Capital (VC)-backed companies. DP: downside protection, COI: Certificate of Incorporation, CP: conversion price, CR: conversion ratio, CSE: common stock equivalent, LP: liquidation preference, OIP: original issue price, IPO: initial public offering, IRR: internal rate of return, MOIC: multiple on invested capital, , ROFR: right of first refusal

Preferred stock rights	**Description of economic characteristics**
Convertible	Includes both DP and a conversion feature. Effectively, it represents a subordinated debt claim plus a call option with a strike price equal to the CP, adjusted to account for the applicable CR.
Non-convertible	Includes only DP and effectively represents a subordinated debt claim with no further upside.
Participating	Includes both DP and upside through common stock participation. Effectively, it is a subordinated debt claim plus a specific number of CSE shares depending on applicable CR.
Participating with cap	Preferred stock accrues value based on DP plus common stock upside, based on applicable CR, until the cap threshold is reached. After the common stock shares catch-up on the cap-threshold value, they share the same upside characteristics with participating preferred stock shares.
LP multiple	Specifies the multiple applicable to the OIP and any potential dividend rate, if applicable, in connection with the DP.
Cash dividend	Dividend right that entitles holders to incremental LP claims and indirectly increases the effective conversion price at which a preferred stockholder would elect to convert their holdings into common stock to account for higher intrinsic LP value.
PIK dividend	Dividend right that entitles holders to incremental LP claims and an adjustment of the conversion upside by assuming that accrued and unpaid dividend return amount can be converted into common stock shares at the same conversion price as the preferred capital contribution balance.
Senior	Reflects the order of economic claims once any interest-bearing debt obligations are repaid. Senior instruments are eligible for priority economic claims based on the contractual order specified in the COI.
Pari-passu	Reflects the same seniority order for preferred stock classes but allocation relative to the weights of respective LP claims.
IPO ratchet	IPO protection right that entitles holders to a minimum IRR or MOIC, if the stock price as of the IPO date falls below a specific level.
IPO veto	Hold-up right that could potentially affect liquidity plans, transaction closing or overall allocation mechanisms.
Weighted average anti-dilution	Consolidated ownership interest protection right for preferred shareholders that allows them to minimize dilution upon issuance of new preferred stock at a lower OIP.
Full ratchet anti-dilution	Consolidated ownership interest protection right for preferred shareholders that allows them to convert at the lowest OIP of subsequently issued preferred stock classes.
Redemption	Entitles holders to the put right to redeem their shares at a specific value, which usually mirrors the LP or intrinsic capital contribution amount.
ROFR	Allows existing shareholders early access in potential purchase or sale of equity interests before initiating offering procedures with potential external willing buyers.
Tag-along / Co-sale	Entitles minority shareholders to a participating right in contemplated liquidity transactions by controlling shareholders, based on the same set of underlying conditions and pricing characteristics.
Drag-along	Entitles majority or controlling shareholders to require minority shareholders to participate in a contemplated transaction and sell their interests based on the specified pricing characteristics.

Table 2: VC sample characteristics

This table summarizes our Venture Capital (VC) sample properties. Panel A provides a breakdown of companies based on number of financing rounds prior to the first exit event (if any). Panel B shows the population distribution per exit type, while Panel C summarizes sample characteristics per preferred stock type. Panel D shows the sample breakdown depending on VC contract seniority, while Panel E shows the average time between financing rounds. Panel F illustrates the average deal size across all rounds, while Panel G describes the deal size sample population as of the last financing round. Panel H outlines sample distribution based on the latest reported investment amount relative to the post-money valuation (PoMV), and Panel I presents sample grouping depending on reported PoMV as of the latest round prior to the first exit event (if any).

Panel A: Number of financing rounds	
2 financing rounds	250
3 financing rounds	454
4 financing rounds	458
5 financing rounds	372
6 financing rounds	254
7 or more financing rounds	268

Panel B: Exit Type	
IPO	145
SPAC	49
Change of Control	33
M&A	251
LBO	12
Still private	1566

Panel C: Preferred type	
Last financing round	
Convertible	1944
Participating	112
Any round	
Convertible	1895
Participating	161

Panel D: Seniority	
Last financing round	
Pari-passu	1631
Senior	425
Any round	
Pari-passu	1357
Senior	699

Panel E: Average financing round period	
Less than 1 year	421
Between 1 and 2 years	1207
Between 2 and 3 years	310
Between 3 and 4 years	78
More than 4 years	40

Panel F: Average deal size across all rounds	
Less than $5 million	1318
Between $5 million and $10 million	485
Between $10 million and $20 million	183
Between $20 million and $50 million	59
More than $50 million	11

Panel G: Last round deal size	
Less than $5 million	716
Between $5 million and $10 million	597
Between $10 million and $20 million	481
Between $20 million and $50 million	214
More than $50 million	48

Panel H: Deal size versus last round PoMV	
Less than 5%	306
Between 5% and 10%	531
Between 10% and 15%	492
Between 15% and 25%	506
Higher than 25%	221

Panel I: Last round PoMV	
Less than $25 million	265
Between $25 million and $50 million	659
Between $50 million and $100 million	442
Between $100 million and $500 million	588
More than $500 million	102

B. Finnerty put option model

Discount for lack of marketability (DLOM) is a well-established concept in business valuation, particularly for non-listed private companies. The securities of a privately held company are subject to illiquidity and transferability restrictions, if they are not associated with any strong put option redemption rights than can mitigate liquidity risks; thus, their fair value or fair market value typically reflects a discount relative to marketable value indications of publicly traded equity classes. DLOM is also viewed as an incremental premium on the ROE expectations of market participants, due to the illiquid nature of the contemplated asset, which has a negative effect on the concluded value. In the context of our paper, we determine the appropriate DLOM for the value of SBC awards utilizing a put option pricing model. Put option pricing models introduce the concept that, in order to hedge the lack of marketability risk, the investor could theoretically use a long-put option strategy. This strategy allows the investors to sell their interest at a predetermined price, essentially protecting against downward price movements. In this case, we employ the Finnerty (2012) model, which considers the average price of the asset during the holding period to derive the strike price for the put option. By using an average-strike put option, the investor is equally likely to sell the shares at any point in time during the marketability restriction period. Under this framework, the lack of marketability translates to a lost opportunity to sell the asset at a higher price before the end of the period, ultimately reflecting the increased risk and reduced liquidity associated with the subject interest investment.

Before applying the Finnerty model, an important input that needs to be calculated is the security-specific equity volatility σ_j, which is the volatility of the underlying asset. The 2019 AICPA suggests a formula for calculating this volatility parameter, which based on our mathematical notation, is defined as follows[23]:

$$\sigma_j = \frac{\sigma E_{t_n}}{e^{-r\Delta t_n}\pi_j} \sum_{i=1}^{i_n} \omega_{ji} \left[N\left(d_1(E_{t_n}, B_i, r, \sigma, \Delta t_n)\right) - N\left(d_1(E_{t_n}, B_{i+1}, r, \sigma, \Delta t_n)\right)\right]. \tag{25}$$

The security-specific volatility σ_j is different than the equity volatility σ of a company with multi-shares capital structure. Securities with higher idiosyncratic risk profile and junior equity claims, like the options, are subject to higher standard deviation relative to securities with senior equity claims like default VC preferred securities. The equity volatility of a VC-backed company is typically the weighted average volatility of all the contemplated securities, such that a deviation of relative risk profiles between equity classes with strong

[23] Refer to Paragraph B.08.07 of the 2019 AICPA Guide Appendix for more details. According to the 2019 AICPA Guide, the class-specific volatility formula derivation is based on Beaton et al. (2009).

investor rights (preferred stock classes) and equity classes with subordinated riskier economic claims (common stock, options) and specific deal characteristics have been already incorporated in the consolidated standard deviation of assets (σ). As a result, the valuation of options on a nonmarketable basis is typically performed using the class-specific equity volatility σ_j that corresponds to the risk profile of the underlying security. According to Finnerty (2012), the DLOM can be calculated as follows:

$$DLOM = e^{-\delta \Delta t_n} \left[N\left(\frac{\nu\sqrt{\Delta t_n}}{2}\right) - N\left(-\frac{\nu\sqrt{\Delta t_n}}{2}\right)\right], \tag{26}$$

where δ is the dividend yield of the equity security and

$$\nu\sqrt{\Delta t_n} = \sqrt{\sigma_j^2 \Delta t_n + \ln\left(e^{\sigma_j^2 \Delta t_n} - \sigma_j^2 \Delta t_n - 1\right) - 2 \cdot \ln\left(e^{\sigma_j^2 \Delta t_n} - 1\right)}. \tag{27}$$

An important takeaway from the aforementioned formula is that (i) a higher security-specific volatility or (ii) a longer holding period, leads to increased DLOM, all else equal. Finally, for longer effective investment periods or higher derived volatility metrics, the Finnerty model indicates that DLOM increases at a progressively slower rate, eventually reaching a maximum value of approximately 32.3%.

C. List of abbreviations

AVD	Asset value delta
CCPR	Concluded conversion probability
CEV	Concluded equity value
COI	Certificate of Incorporation
CP	Conversion price
CPR	Conversion probability
CSE	Common stock equivalent
CV	Concluded value
DLOM	Discount for lack of marketability
DP	Downside protection
DS	Deal size
EV	Equity value
FD	Fully diluted
GPC	Guideline public companies
IPO	Initial public offering
IRR	Internal rate of return
LP	Liquidation preference
LPY	Liquidation preference yield
OIP	Original issue price
OPM	Option pricing method
PE	Private equity
PIK	Paid-in-kind
PoMV	Post-money valuation
PrMV	Pre-money valuation
RA	Recovery amount
ROE	Return on equity
ROFR	Right of first refusal
VC	Venture capital
VCs	Venture capital funds