Do Investors Overvalue Startups?
Evidence from the Junior Stakes of Mutual Funds

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Abstract

We show that mutual funds report their junior stakes in startups at 43% higher valuation than model fair values that consider multi-tier capital structures of startups. The latest-issued and most senior security is worth 48% more per share than junior securities held by mutual funds, implying that mutual funds mark junior securities close to par with the senior securities. Our findings are robust to model assumptions. Identical valuations reported for dual holdings of senior and junior securities imply 37% discrepancy in implied values of the firm. Overvaluation is lower for fund families with longer experience in private startup investments, and higher for junior securities purchased in secondary transactions. Overvaluation declines after down rounds (new financing rounds with purchase prices lower than previous rounds) and near IPOs. The results are consistent with mutual funds neglecting the probability of negative outcomes in which junior securities are paid less than senior securities and overweighting successful exits where all securities convert to common equity and are paid equally.

Keywords: Startup financing, Startup valuation, Mutual funds, Venture capital, Fair value, Private valuation

JEL Codes: G23, G24, G28, G32

1. Introduction

In the decade following the Financial Crisis of 2008-2009, the annual flow of investments into U.S. private startup companies rose dramatically. This was accompanied by both breakthrough technological advances as well as unprecedented direct investments in startups by non-traditional investors. While the US private startup investments stood at $27.2B and 0.19% of U.S. GDP in 2009, by 2021 it had reached a record-breaking $344.7B and 1.51% of GDP.[1] The rapid pace of increase is reminiscent of the internet bubble that peaked in 2000 when more than $100B was invested in startups – many of which subsequently failed – with one exception: the surge of non-traditional investors. In 2000, virtually all of the $100B investments were intermediated through traditional venture capital (VC) funds, whereas in 2021, non-traditional investors such as mutual, hedge, pension and sovereign-wealth funds participated in 41% of all deal counts (82% of dollars provided) and solely funded or led 17% of the deals (45% of the dollars provided).[2] The surge of new capital supplied by non-traditional investors raise the questions of whether the new investors value their stakes in startups fairly. This paper examines this question using reported valuations of private startup securities held by mutual funds and provides the first empirical evidence that considers the complex and opaque capital structure of startups.

In the U.S., VCs almost always use preferred stock in their transactions (Kaplan and Stromberg 2003, Metrick and Yasuda 2010, 2021). This distinguishes VCs from angel investors, who tend to use common stock or securities that get priced in subsequent VC rounds. The key characteristics of preferred stock are that it has a liquidation preference to common stock and an optional conversion to common. This implies that at the time of exits (called liquidation events) from investments, VCs optimally choose to redeem their preferred stock as senior securities to common when exit firm values are low, and to convert to common when exit firm values are high. This contingent payoff function makes preferred stock more valuable than common. Furthermore, VCs make lumpy investments in startups organized into sequential rounds, and a new unique series of preferred stock is created for each round, resulting in a complex, multi-tiered capital structure with multiple series of preferred stock (named Series A, Series B, etc.) held by investors and the common stock held by founders and employees. Contract terms of each series of preferred stock differ from one another and are described in the Certificate of Incorporation, a document that startups file with the state of incorporation.

[1] Pitchbook-NVCA for VC investment data, and the World Bank for GDP data.
[2] Pitchbook-NVCA Yearbook 2022 and Pitchbook-NVCA Venture Monitor Q3 2022.

Often a later-series preferred has a liquidation preference to an earlier-series preferred stock, providing more downside protection, and thus it is more valuable, just as preferred in general is more valuable than common. In the remainder of the paper, we refer to earlier-series preferred stock as junior stakes, and later-series preferred stock as senior stakes, to indicate their relative seniority in liquidation preference, analogous to senior and junior debt's relative seniority in recovery after bankruptcy.

Despite this complex capital structure that private VC-backed startups typically have, the most heavily used term to describe the market value of the startup firm – post-money valuation – ignores the differences in values between the most recently issued preferred stock and the rest. Instead, it is calculated as the price per share paid by investors in the latest funding round, multiplied by the fully diluted share count of the company, where all convertible preferred and exercisable options/warrants are assumed to be converted/exercised to common. The thought exercise would be if this startup had an IPO on the date of the funding round and all private, restricted securities were forced to be converted into publicly traded common stock instantly, and the IPO price equaled the purchase price of the latest round preferred stock (which would also be converted), then the market capitalization of the startup would hypothetically be equal to the post-money valuation. Under this thought experiment, all securities have the same exit payoffs, namely the IPO price of common stock. To nontraditional investors who participate in late-stage VC deals with expectation of IPOs soon after, this notion of pseudo market capitalization may seem reasonable; indeed, nontraditional investors sometimes refer to these late-stage VC rounds as "private IPOs".

But in practice, the preferred investors reserve their rights to redeem rather than convert their preferred stock, and in some cases "double-dip" by earning both the redemption value and the conversion value when exit values are below a pre-specified threshold. IPO markets are highly cyclical, and when the IPO windows close, those low value exits, where payoffs to senior and junior investors diverge, become more common ex post. The present values of junior stakes should reflect the probability of future negative outcomes for startups. The question is, do investors in general and nontraditional investors in particular recognize these valuation differences between senior and junior stakes in private startups? Or do they overweight the probability that startups they invest in end up going public and the payoff difference between junior and senior securities disappear? Does their collective valuation practice amplify misvaluation of startups and worsen the boom and bust cycle? These are the questions we examine and shed new light on in this paper.

Specifically, we ask the following questions.

1. How much do senior and junior securities of startups with mutual fund investments differ in model fair valuations? To answer this question, we build and estimate an option-pricing based model of contingent claims.
2. How do mutual funds report their junior stakes in startups relative to model fair values?
3. Do fund family characteristics affect their valuations?
4. Do changes in startup-specific or market-wide conditions affect their valuations?

We focus on mutual funds among the nontraditional investors in startups for two reasons. First, unlike VC, pension and sovereign wealth funds, whose fund liability has a very long, predictable duration and is therefore well suited to hold long-term illiquid assets such as stakes in private startups, mutual funds have an open-ended structure and are required to provide on-demand liquidity to investors, much as banks funded by depositors do. Agarwal, Barber, Cheng, Hameed, and Yasuda (2023) provides evidence that this fund structure exposes mutual funds with illiquid investments in startups to greater financial fragility. Thus, misvaluation by mutual funds is potentially more consequential. Second, mutual funds' valuations of startups are publicly available through their SEC filings. This is in contrast to hedge funds, which are also subject to withdrawal requests from investors but whose valuations of startups are not available to researchers.

To answer the first question, we estimate an option-pricing based model of contingent claims developed by Metrick and Yasuda (2010, 2021). Each security in a multi-tier capital structure of startups has exit payoff claims upon liquidation events. The payoff is dynamically contingent on relative seniority in liquidation preference, optimal conversion decisions by respective tiers of investors, participation features, conversion ratios, and cumulative dividends, if any, among other features. These contingent conditions are incorporated as combinations of option-like claims on the enterprise values of the startups upon liquidation events (much like an option payoff on an expiration date as a function of the share price) and the security's present value is evaluated. To back out the fair value of junior securities held by mutual funds as of the date of the issuance of a senior security, we assume that the senior security is issued at a fair price, i.e., its purchase price equals its present value and find a unique enterprise value of the startup today with which this condition holds. Using this implied value of the startup firm, we estimate the implied fair value of the junior securities.

We find that on average, the latest-issued and most senior security is worth 48.5% more per share than junior securities held by mutual funds in model fair values. This number is calculated using only securities that mutual fund families directly purchased from startups themselves in funding rounds as primary investors. When we include securities that mutual fund families purchased in secondary transactions and held as of the senior security issue date, the mean fair value difference rises to 62.9%. The securities purchased in secondary transactions tend to be earlier series than those purchased in primary transactions, and on average are worth less in model fair values. This is both because the liquidation preference amounts that they are entitled to tend to be smaller and also because they tend to be more junior in liquidation preference.

Our baseline assumptions use 90% annual volatility, 3 years expected holding period for investments (akin to option expiration dates), and 3% riskless rate. These assumptions likely underestimate the valuation differences in senior and junior stakes because we calibrate to the typical experience of VC-backed private companies, which tend to be smaller, more volatile, and further from a liquidation event than the private companies preferred by mutual fund investors. We analyze the sensitivity of our results with respect to the model assumptions about the underlying enterprise value volatility, the expected holding period, and the current enterprise value of the startup (akin to the current stock price as an input to an option pricing equation). We show that key inputs (enterprise value volatility, expected holding period for the security, and current enterprise value relative to post-money valuation) would need to increase to unrealistic levels to close the valuation gap between senior and junior stakes: annual volatility to over 300%, the expected holding period to over 15 years, or the current enterprise value of the startup would need to be more than five times its post-money valuation. These threshold levels are significantly above the norm in the VC industry practice, thus suggesting that our results about model fair value differences between senior and junior securities are robust and not sensitive to the assumptions used.

Having established that junior securities held by mutual funds have significantly lower fair value per share than the senior securities just issued, we now compare the values for these securities reported by mutual funds to their fair values. We find that mutual funds who purchased them in primary transactions value the securities on average at 43.3% above the fair values. Given that the senior security purchases price is 48.5% above the fair values, this result implies that mutual funds value their junior securities close to par with the senior securities just issued. When we include securities bought in secondary transactions, the gap between the reported value and the fair value increases to 67.8%.

We analyze instances where a fund family reports the same price per share for multiple securities issued by a given startup at the same time. Since these securities have different contractual rights regarding their exit payoff, they cannot both be fair-valued and have the same price at the same time. To gauge the magnitude of internal inconsistency in valuing two different securities at the same price, we back out the enterprise value of the startup firm implied by fair pricing of one security at a time and compare the two implied enterprise values of the firm. On average, the two enterprise values differ from each other by 37%. This suggests that the mutual funds' practice of valuing two securities at the same price is sharply at odds with our model which incorporates the major contractual differences between them. Nor can their practice be rationalizable by changing the option-pricing assumptions. As reported earlier, the assumptions that make the value differences between securities diminish to inconsequential levels are either implausible (e.g., the firm is worth 5 times the post-money valuation today) or unlikely to be the assumptions held by mutual fund investors in private startups (e.g., they will hold the security for 15 years before liquidation events).

One possibility is that some mutual funds ignore the probability of non-IPO exits and assume that their preferred stock is converted to a share of common stock at a 1:1 ratio with 100% probability soon. Under such a belief, holding both senior and junior securities at the same price can be rationalized, provided that both securities have the same conversion ratio. If such beliefs are products of naivete or lack of knowledge about VC contracts, we expect them to be negatively correlated with (i) their experience in private startup investments and (ii) their information cost and/or access to the startups. Ceteris paribus, the more experienced the investors are, the more they differentiate the values of senior and junior securities. Similarly, the more information access the investors have to the private startups who issue the securities, the more they differentiate the value of senior and junior securities. We test these cross-sectional hypotheses and obtain mixed evidence. On the one hand, we find that fund families with longer experience in private startup investments deviate less in their reported values from the model fair values, supporting our experience or sophistication hypothesis. Similarly, we find that investors who participate in primary transactions (and interact directly with the issuing firm) deviate less from the model fair values than investors who buy the securities in secondary transactions (and thus have no information access to the issuing startups). On the other hand, neither the size of their private startup portfolio nor the share of a round that they invest – a measure of information cost effectiveness and access, respectively – is associated with smaller deviation. One possibility is that these measures pick up fund families' effectiveness in updating the enterprise value of the startups as a whole, but not the relative values of senior and junior securities.

Another possibility is that investors Bayesian update their assessment of the values of senior and junior preferred stock. After a negative shock to the firm's overall enterprise value, such as a down round, investors might increase the probabilistic weight on the negative exit outcomes and differentiate the junior and senior security values more. Furthermore, if down rounds (or other negative events) result in adjustments to securities' conversion ratios, such that a share of preferred converts to x shares of common where x is no longer 1, then such an update might prompt mutual funds to recognize that even upon conversion to common stock, some preferred stock converts to more common shares per share than others, and therefore have different present values. We examine this time-varying hypothesis and obtain evidence in support of investor Bayesian updating. After a down round, the mutual funds' reported values deviate significantly less from the model fair values. Having a conversion ratio adjustment as a result of a down round has an additive negative effect on the excess valuation reported by mutual funds over the fair value.

Do mutual funds indeed exit via IPOs at near 100% probability? We track the exit outcomes of first mutual fund investments in startups for 5 years and compare them to late-stage Series C VC investments. Interestingly, while mutual fund investments have significantly higher probability of exiting via IPOs (45%) than VCs (14%), the overall exit probabilities are both about 60% after 5 years, and about 40% of investments remain private and illiquid. Mutual funds thus prioritize investing in firms that go public more than VCs do, but they do not achieve any higher overall exit rate. In VC markets, historically the best exit outcomes tend to occur quickly and within 5 years, and investment held longer are less likely to be successful. Thus, it is difficult to rationalize the mutual funds' practice of valuing junior securities close to par with the senior securities ex post based on this track record.

Do mutual funds that anticipate IPOs on the near horizon act more aggressively by marking junior security at par with senior security, thus skewing the overall results? If so, we should find that fund families whose portfolio companies have an IPO within the next 12 months mark up their junior securities more aggressively towards the senior security's purchase price than fund families whose portfolio companies remain private in the next 12 months. By the same token, we also expect fund families whose portfolio companies experience negative events in the near future (e.g., bankruptcy) value junior and senior securities more differentially because they anticipate a higher likelihood of negative exit outcomes. We test these anticipatory adjustment hypotheses and find results that are inconsistent with mutual funds changing their probability weights of successful vs. negative exit outcomes in anticipatory manner. When portfolio firms are within 12 months of IPOs, fund families actually deviate significantly less from the fair values than when they are not. In other words, the overall results we report are not driven by portfolio companies that are on the cusp of going public.

Are mutual funds naively optimistic, or strategically inflating the reported values of junior securities, while being aware that they have lower values than senior securities? We address this question in two ways. First, we report that when mutual funds purchase junior securities in secondary transactions, their first reported value, which is likely to be close to their purchase price (since the purchase occurred within a quarter), is significantly higher than the model fair values. Second, we also report anecdotal evidence that when mutual funds explicitly report acquisition cost per share of secondary purchases of junior securities, the reported acquisition cost significantly exceeds the model fair values of those securities. Both results are consistent with naïve /optimistic valuation mistakes by mutual funds, and inconsistent with strategic overstatement of reported values.

Finally, we construct an aggregate industry-level measure of deviation between the self-reported values of junior private securities held by mutual funds and their model fair values. We find that junior securities are held on average at 44% above the fair values in the aggregate (with an inter-quartile range of 34% and 50%). For example, in the 3rd quarter of 2018, the total junior securities held by mutual funds were reported to be worth about \$7.1 billion, whereas the fair values for these holdings were worth about \$4.8 billion. In other words, reported values were 48% above the fair values. Taken together, these findings suggest that mutual funds underweight the probability of negative outcomes in which junior securities are paid less than senior securities and overweight successful exits where all securities convert to common equity and are valued equally. This has implications especially when IPO prospects dim in market downturns and the negative exit probability rises.

We are currently updating our analyses to include IPO cancellations and internal company valuation cuts as another Bayesian updating event type. We are also extending the sample to 2022 to study the impact of market downturns (e.g., in 2022) on the mutual fund valuations relative to the fair values.

We contribute to the literature in two ways. First, by estimating model fair values and then comparing them to reported values by mutual funds, we infer whether mutual funds misvalue their junior stakes in private startups. Anchoring the reported valuation with fair values is a step in the right direction in assessing whether the practice behind the reported values is unbiased or internally consistent. Our findings suggest that the reported values are on average significantly higher than fair values. Second, we explore the determinants of this overall high valuation of junior securities. The above-fair-value valuation is modulated for more experienced fund families, whereas it is more pronounced for secondary market buyers. The above-fair-value valuation declines after the startup experiences a down round and disappears altogether after a conversion ratio is adjusted such that different series of preferred end up becoming convertible to different shares of common. These inferences are made by combining complex and opaque contract data with an option-pricing based model, and further matching them with detailed purchases and holdings data of illiquid securities by mutual funds.

2. Related Literature and Our Contributions

Our paper is most closely related to two strands of the literature, one studying mutual fund investments in private startups, and another building and estimating models of implied valuation for multi-tier capital structure firms, such as VC-backed private startups. Our paper is one of the first at the intersection of these two strands of literature. Below we summarize each.

In the first strand, Kwon, Lowry, and Qian (2020) analyze the general rise in mutual fund participation in private markets over the last 20 years and conclude that mutual fund investments enable companies to stay private one or two years longer on average. They also find that mutual fund investments in private startups earned higher returns than the hypothetical returns they would have earned investing in the public equity markets during the same period and that the risk, if higher is likely largely idiosyncratic. Chernenko, Lerner, and Zeng (2021) analyze contract-level data to examine the consequences of mutual fund investments in these early-stage companies for corporate governance provisions. They find that mutual funds with more stable funding are more likely to invest in private firms and that financing rounds with mutual fund participation have stronger redemption, stronger IPO-related rights, and less board representation. Huang, Mao, Wang, and Zhou (2021) study the performance of private startup firms backed by institutional investors and find that they are more mature, have higher likelihoods of successful exits, and in case of IPO exits, receive lower IPO underpricing and higher net proceeds. Agarwal, Barber, Cheng, Hameed and Yasuda (2023) study cross-fund family valuation practice differences and find that fund families with better information cost and/or access have better valuation practices. They also find that high-private-equity-exposure funds are subject to greater financial fragility. Imbierowicz and Rauch (2023) study the relative importance of company fundamentals vs. comparable valuations in determining mutual funds' reported valuation of private startups and find that comparable peer firms' valuation plays a more dominant role. Cederburg and Stoughton (2018) document variation in pricing across funds and argue that private equity pricing by mutual funds is pro-cyclical with respect to fund performance, which is consistent with the prediction of a theoretical model that they develop.

Our paper focuses on the reported interim valuations of junior stakes by mutual funds and compares them to model-implied fair values that reflect the multi-tier capital structures of VC-backed startups. By anchoring the reported values by mutual funds vis-à-vis the model fair values, we measure the extent to which mutual funds misvalue their private holdings under the assumption that the model is right. We also impute the conditions under which reported mutual fund valuations are "right" and then assess whether those conditions are realistic or reasonable.

In the second strand, Metrick and Yasuda (2010, 2021) develop an option-pricing based model to estimate the value of VC investments in private startups as the present value of future exit payoffs. They also build a model to back out the current enterprise value of the startup on the date of a funding round by using an assumption that the security issued in the latest funding round is fairly price, i.e., its purchase price equals the present value of its future exit payoff. Then, using this model-implied enterprise value as one of the inputs to the Black-Scholes call option formula, the same model can be used to back out implied fair values of all the other junior securities issued by the startup, including the common stock. The authors show that, since the security in the latest round is typically more senior and more valuable, the implied fair values of junior securities are often significantly lower, and as a result the implied enterprise value is typically lower than the post-money valuation. Gornall and Strebulaev (2020) build a similar model and apply it to the actual funding history of a sample of unicorns, or private startups with post-money valuations of $1B or greater. They find that the implied enterprise values are significantly lower than the post-money valuations, such that a significant portion of the so-called unicorns had in fact implied enterprise values below

$1B on the date they were minted as unicorns. Gornall and Strebulaev (2022) apply an extended model to a larger VC-backed firm sample and report high value of most recently issued preferred stock relative to the common. They compare their model values to a mutual fund data sample obtained from Imbierowicz and Rauch (2023) and find that junior security values reported by mutual funds are not significantly related to their model implied fair values.

Our paper takes the contingent claims valuation methodology developed in Metrick and Yasuda (2010, 2021), applies it to the actual funding history of private startups that received funding from mutual funds, and compares the implied fair values of junior securities to the *actual* contemporaneous reported values of the securities by mutual funds. We show that our results are robust to model assumptions and demonstrate internal discrepancy in mutual fund valuations of dual holdings of senior and junior securities at the identical price. We examine cross-sectional and time series variation in the discrepancy and assess whether the large deviations by mutual funds from the model fair values are ex post justifiable or misguided. We measure not only the individual valuation discrepancy between the actual and the model values but also construct the aggregate discrepancy measures at the mutual fund industry level. Our results are more consistent with mutual funds' inattention to the contractual differences between senior and junior securities than with strategic management of security values.

3. Model

3.1 Preferred Stock in VC Contracts

When VC funds invest in startups, they almost always purchase shares of convertible preferred stock issued by the startup, rather than common stock (Kaplan and Stromberg 2003, Metrick and Yasuda 2010, 2021). There are two main privileges of these securities over the common stock. First, preferred stock has a liquidation preference, meaning that when the startup has an exit event whereby the stakes in the startup become liquid – e.g., via an IPO, an M&A, or a bankruptcy and subsequent asset liquidation – the preferred stockholder has a senior claim to the liquidation proceeds. These events that make the stake in the firm liquid are called "deemed liquidation events" and are named in the VC investment contract. As a default, the amount of senior claim is equal to the purchase price that the investor paid for the security. Second, preferred stock also has a dividend privilege, meaning that they must be paid dividend before the common stockholder is entitled to a dividend. Between the two, the liquidation preference is significantly more material in determining the division of the liquidation exit proceeds among the founders, employees, and the investors.

To illustrate the impact of the liquidation preference on the division of exit proceeds, we use exit diagrams, which plot the exit payoff to a given investor on the y-axis as a function of the value of the enterprise on the x-axis. For example, for a 30% equity owner of an all-equity-financed startup with no debt and no preferred, the exit diagram will look like Figure 1.

[Figure 1 inserted here]

Suppose a VC invests in Series A $5 million investment in a startup structured as follows:

- 5 million shares of convertible preferred with aggregate purchase price (APP) of $5 million.
- Founders have 5 million shares of common.

Note that when the enterprise value of the startup at exit is at or below $5 million, Series A receives the entire proceeds amount, leaving nothing to the founders. Series A exercises its option to convert to common if the firm exit value is $10M or higher – otherwise, it redeems. This is because at the enterprise value at exit of $10M, Series A would receive $5 million if it redeems the convertible preferred stock, and it would also receive if $5 million if it inverts it to common, and becoming a 50% common shareholder. For an enterprise value at exit above $10 million, it is strictly better off if it converts. Figure 2a presents an exit diagram of this contingent claim by Series A, and Figure 2b presents an exit diagram for the founders. The sums of the payoffs of the two parties equal the total enterprise value at exit.

[insert Figure 2 here]

Since the payoff for Series A is strictly higher than that of the founders at exit enterprise value at or below $10 million, a positive probability of exit in this exit value range ($0-$10 million) implies that the present value of the Series A convertible preferred stock is strictly greater than the present value of common stock held by the founders. The probability of exit in this low exit value range is likely to depend on multiple factors, such as: the value of the firm on the date of the Series A investment, the fluctuation in the value of the firm between the date of the investment and the liquidation event, and the time it takes to the liquidation event.

3.2 Option-Pricing Model of Preferred Stock Valuation

In this paper we employ an option-pricing model framework developed by Metrick and Yasuda (2010, 2021) that considers key features of VC contracts such as liquidation preference, conversion, participation, dividends, and so forth and so on. In this section we present the key intuition of the model using simple examples. See Metrick and Yasuda (2021) and an online appendix for more details of the model.

Suppose founders own 50% of common stock, and Series A has a redeemable preferred stock with liquidation preference for $5M, plus the other 50% of common stock. Note that in this example, the redeemable preferred stock is only redeemable, and not convertible, so its main value is the liquidation preference over common. For the first $5M of the firm exit value, Series A investors claim the entire exit proceeds by redeeming the preferred, and the founders are "out of the money" and get "in the money" only above $5M, as illustrated in Figure 3. The shape of the founder's stake in the firm in Figure 3 resembles that of a European call option expiration diagram, with the per-share value of common stock on the x-axis and the payoff on the expiration date on the y-axis. We model the founders' stake in the firm as equivalent to a 50% fraction of a call option written on the enterprise value of the firm with a strike price of $5 million. In place of an option expiration date, we use a date of a liquidation (exit) event for the firm.

[Insert Figure 3 here]

Denote by *C(x)* a call option on the enterprise value of the firm with a strike price of x. It turns out that a contractual stake in a firm, characterized by its exit diagram on the exit date, can be expressed as a linear combination of (fractions of) such call options. We define this algebraic expression of an exit diagram as an exit equation. Continuing with the above example of 5 million shares of convertible preferred stock (shown in Figure 2), now we can write the exit equation of Series A's stake as:

$$C(0) - C(5) + \frac{1}{2}C(10) \quad (1)$$

And the exit equation of the founders' stake is:

$$C(5) - \frac{1}{2}C(10) \quad (2)$$

Note that the sum of the two exit equations equals C(0), or the value of the firm *V*.

Having converted a contractual stake in a firm to a linear combination of call option-like claims on the firm, now we need to operationalize valuing individual call options. We start with the Black-Scholes formula for European call options and make a few extensions. According to the formula, the value of a European call option on date 0 is:

$$C_0 = N(d_1)S_0 - N(d_2)Xe^{-rT} \quad (3)$$

where S_0 = current enterprise value, X = strike price, T = time to expiration, r = risk-free rate, and σ = enterprise value volatility. We assume that no cash dividends are paid before the liquidation event date, which is in line with the empirical evidence that these startups burn more cash than internally generated earnings (if any) and if any dividends are declared before the exit date, they accrue unpaid to be paid out only upon the liquidation events (Metrick and Yasuda (2021). These accrued dividends then become part of the investors' exit payoff as a function of time to exit.

Once the exit happens, all options embedded in the exit equation expire on that date and the investors receive the expiration payoff of a given option according to the exit value of the enterprise. But ex ante liquidation event (exit) dates, unlike the contractual expiration dates of call options, are uncertain. So we model the uncertainty in the exit date by assuming that it follows the exponential distribution function. The continuous-time probability of expiring in an instant is q and the probability that an option remains alive and has not expired yet on a given date T is e^{-qT}. We define this modified version of the Black-Scholes call option as a random-expiration (RE) call option. The value of a RE call option is:

$$\int_0^\infty [N(d_1)S_0 - N(d_2)Xe^{-rT}]qe^{-qT}dT \quad (4)$$

This integral is solved numerically in our model. Note that the mean of the exponential distribution, $\frac{1}{q}$, is the expected duration between the investment and the exit, or the expected holding period. So instead of using *T* = time to expiration, we instead use *H* = expected holding period as one of our model inputs.

Continuing with the above example of Series A investment, suppose:
(i) S_0= current enterprise value = \$10 million; (ii) EHP (expected holding period) = 5 years; (iii) r= risk-free rate = 3%; and (iv) σ = volatility= 90% per annum. Using these inputs in Equation (3) and the RE call option formula in Equation (4), we can evaluate the present value of Series A's stake in the firm, as expressed in Equation (1), as

$C(0) – C(5) + \frac{1}{2}C(10)$ = \$5.5903 million. Similarly, the present value of the founder's stake in the firm is $C(5) - \frac{1}{2}C(10)$= \$4.4097 million. On per-share basis, Series A's preferred stock is worth \$1.12 (=\$5.5903M/5M) vs. founders' common stock of \$0.88 (\$4.4097M/5M), or the Series A preferred is worth 27% more than common per share ((\$1.12/\$0.88) -1 = 27%).

3.3 Implied Fair Value of Junior Securities

We now use this model apparatus to infer the fair value of junior securities as of the time of the senior security financing. In VC financing rounds, outside investors typically lead each round of financing. Whereas insiders may have incentives to prop up a failing venture by inflating the purchase price of a new round, outside insiders presumably would accept only a fair deal where the purchase price equals the present value of its expected exit payoff. Thus, we assume that the latest funding round purchase price is fair, or the present value of the latest round security per share = its original purchase price, and use this assumption to back out both (i) the implied post valuation of the enterprise and (ii) the implied fair value of junior securities (or implied partial valuation).

Instead of assuming that the firm was worth \$10M as of the Series A financing, now we search iteratively for the value of the firm such that the Series A investment is worth \$5M for the series, or worth \$1 per share, so that is NPV is \$0. S_0 that satisfies this condition turns out to be \$8.75M. We define this as the implied post valuation of the firm, or S_0^*.

Using the implied post valuation of \$8.75M as S_0 on Series A's investment date, now we calculate the implied fair value of the founder's stake. This is $C(5) - \frac{1}{2}C(10)$ (with $S_0 = \$8.75\text{M}$)= \$3.7517 million. We define this as the implied fair value of the junior security, or the implied partial value. On a per-share basis, founder's common stock is worth \$3.7517M/5M = \$.75, relative to the Series A preferred stock, which by definition of fair transaction is assumed to worth \$1/share. Thus, Series A's preferred stock is worth 33% ((\$1/\$0.75) – 1) more than the common stock. Though this example includes only one round of preferred stock financing, we can extend the model to accommodate as many rounds of financing as needed, with the same intuition. The key here is that by using the **most recent transaction price** paid by investors (which is assumed to be fair), we can back out the **fair value** of other illiquid securities in the startup's capital structure, including all other series of preferred stock and the common stock.

In practice, startups receive multiple funding rounds, each with own class of preferred stock. Often the later-round preferred stock has liquidation preference to early-round preferred stock, and thus is senior. Later-round preferred stock also often has greater liquidation preference per share due to the higher purchase price. This seniority and greater liquidation preference amount per share, among other features of the contract, makes later-round preferred stock more valuable than early round preferred stock, just as the liquidation preference makes early-round preferred stock more valuable than the common stock. In a two-round example shown in Figure 4, Series B invests $10 million for 5M shares of convertible preferred that is senior to Series A's 5M shares of convertible preferred (purchased for $5 million). Using Series B's purchase price of $2/share as the fair price, we back out the implied fair value of Series A and the common stock. The implied fair value per share for Series A is $1.36/share, and the implied fair value per share for the common stock is $1.26/share, compared to $2/share for Series B.[3]

Our model incorporates many other contractual features commonly found in VC term sheets. For example, VC preferred stock often has additional privilege to participate of "double-dip" by redeeming and receiving the liquidation preference and also participating in equity upside simultaneously. For preferred with this participation feature (called participating convertible preferred), the payoff is always higher than that of common, and the preferred stockholders have no incentives to voluntarily convert, unless an IPO occurs. Upon a qualified IPO (conditions for which investors pre-specify and approve), the preferred investor's stakes are forced to be converted to common right before the company completes the IPO. Thus, as long as the conversion ratio for the preferred is 1:1, the per share exit payoffs of preferred and the common are identical after an IPO. This convergence of exit payoffs upon a qualified IPO is depicted in Figure 5. This feature may be salient for mutual fund investors who are experienced participants in IPO markets.

However, there is a significant probability that actual liquidation events (exits) occur at enterprise values below the qualified IPO threshold. In such instances, exit payoffs can differ significantly on per-share basis across senior and junior investors (as well as common shareholders). Suppose Series B = $10M investment for 5M shares with "double dipping" Participating Convertible Preferred and is senior to Series A's 5M shares of Participating Convertible Preferred, purchased at $5M. Founders also own 5M shares of common stock. Suppose that a qualified IPO for both Series A and B is an IPO where the startup is valued at

[3] See Appendix for detailed derivations of these examples.

$75M or higher (excluding the IPO proceeds). The exit diagram as of the Series B investment for this example is shown in Figure 6. Due to the greater liquidation preference ($2/share) and the participation feature, Series B is paid strictly higher exit payoff than Series A as long as the enterprise value at exit is $75M or less. For example, if the enterprise value at exit equals $50M (see Figure 6), then Series B payoff = 10 + (50-10-5)*(1/3) = $21.67M, whereas Series A' exit payoff = 5 + (50-10-5)*(1/3) = $16.67M and the founders' payoff = (50-10-5)*(1/3) = $11.67M. This inequality in payoff disappears for exits with enterprise value at exit above $75M, as both Series A and B is forced to convert to common stock and their exit payoffs converge at $75M*(1/3) = $25M when the enterprise value at exit equals $75M.

In expectation, our option-pricing based framework incorporates the positive probability of exits occurring below $75M in calculating the expected present value of future exit payoffs for each security and value them accordingly. The implied partial valuation per share for Series A security is $1.16/share compared to Series B's (assumed to be fair) $2/share valuation. Thus, marking Series A as worth $2/share on the date of Series B financing would imply a 72% overvaluation (($2/$1.16) – 1 = 72%) according to the baseline model. In the next section we provide robustness for the magnitudes of implied overvaluation by varying key assumptions underlying our model, namely, volatility of the underlying startup enterprise value, the expected holding period, and the current enterprise value of the startup.

Besides the relative liquidation preference, convertibility, and participation, the following additional features of the VC term sheets are incorporated in our model: (i) participation cap; (ii) IPO ratchet; (iii) excess liquidation preference; (iv) pari passu liquidation preference; (v) cumulative cash or in-kind dividends; (vi) anti-dilution protection and down rounds; (vii) stock splits; and (ix) changes in conversion ratios over time. These features affect the exit equations for the senior and junior securities. Note that exit equations for investors are dynamically linked – one investor's decision to convert, for examples, affects the payoff to other investors, and thus optimal conversion decisions need to be determined as best-response functions in a game-theoretic sense. More details on how these features impact the investor exit payoffs and exit equations are discussed in Metrick and Yasuda (2010, 2021) and in the Appendix.

Finally, for each evaluation of implied fair partial values of junior securities, we need to make assumptions about the inputs into the Black-Scholes call option in Equation (3). Following Metrick and Yasuda (2021), we use the following baseline assumptions: (i) EHP (expected holding period) = 5 years for Series A, 4 years for Series B, and 3 years for Series C or later;[4] (ii) r= risk-free rate = 3%; and (iii) σ = volatility= 90% per annum.[5] We vary each of these assumptions in sensitivity analysis and report the results in Section 5.

4. Hypotheses and Data

We now apply our option-pricing based model to the capital structure of mutual fund-backed (and VC-backed) private startups and estimate both the implied fair value of the whole firm and the implied fair values of junior securities as of the date of the newest funding rounds. We assume that the price paid by the newest round of investors to invest in the startup is fair, i.e., the expected present value of the future cash flows to the investors in the latest round equals the purchase price of the securities.

Let *i* and *j* stand for a security (*i*) issued in an early round and a security (*j*) issued in the latest round (at time t_j) by the same startup. The variable $DevDeal_{ijt_j}$ is defined as the valuation difference between the new round deal price per share of security *j* and the implied fair value of an early round security *i* per share at the time of security *j* issuance t_j:

$$DevDeal_{ijt_j} = \frac{Deal\ Price_j}{Fair\ Value_{i,t_j}} - 1, \quad (5)$$

where $Deal\ Price_j$ is the purchase price per share of the security issued in round j, and $Fair\ Value_{i,t_j}$ is the model-implied fair value per share of security *i* at the time of the new round j. Given the typical VC deal structures that award liquidity preference to more senior securities, set higher purchase prices per share in later rounds, as well as additional contractual features that further protect investors against downside risk (e.g., participation and IPO ratchets), we expect that on average a junior security *i* is worth less per share than the most senior security j. More specifically for mutual funds' investments, we hypothesize that:

[4] Since most mutual fund investments are in later rounds, we use 3 years as the EHP in the baseline model for all but 2 firms, and for the 2 firms we use 4 years, as mutual funds participate in Series B for those firms. Dropping these 2 firms from the analyses or using 3 years for all firms does not change our main findings.

[5] Cochrane (1995) estimates 89% as the average volatility of VC portfolio company investments. According to Jay Ritter's IPO data, the cross-sectional standard deviation of one-year returns after IPOs for newly-public firms is 83.4%.

Hypothesis #1: Junior claims held by mutual funds are reliably worth significantly less than the latest issued securities on a per-share basis.

We examine this hypothesis by estimating the variable $DevDeal_{ijt_j}$ for all junior securities held by mutual funds as of the latest funding date t_j. Note that the magnitude is as important as the sign here. If the fair value deviation between the senior and the junior security is small, e.g., 2% of the fair value of the new security (assumed to be equal to its purchase price), then it is not unreasonable for mutual funds to value the junior security at the same level as the senior security's purchase price. If the fair value deviation is 30%, on the other hand, then it becomes more important for mutual funds to treat them as distinct assets and value them differentially.

Next, we examine mutual funds' reported values of junior securities and compare them to the implied fair values of these securities.

Let *i* and *j* stand for a security (*i*) issued in an early round and a security (*j*) issued in the latest round (at time t_j) by the same startup. The variable $DevPrc_{Fit_j}$ is defined as the valuation difference between mutual fund family F's reported value per share of an early round security *i* and its implied fair value per share at the time of a later security *j* issuance t_j:

$$DevPrc_{Fit_j} = \frac{Price_{Fit_j}}{Fair\ Value_{i,t_j}} - 1, \tag{6}$$

where $Price_{Fit_j}$ is the marked price for an early round security *i* reported by mutual fund family *F* at the time of a later round j, and $Fair\ Value_{i,t_j}$ is the model-implied fair value of an early round security *i* at the time of a later round j. When $Price_{Fit_j}$ is not available at the same month of the new round issuance, we employ the first reported price within three months after the new round.

As shown in the previous model section, the expected present value differences between the senior and junior securities often arise from the unequal distributions of exit payoffs in cases of low enterprise value exits where at least some investors optimally choose not to convert their preferred stock to common. These are non-IPO exit outcomes, since in order to have an IPO all preferred stock investors must agree to convert to common stock. In contrast, in IPO exit scenarios the value differences between junior and senior securities arise only if they are entitled to different conversion ratios, i.e., the number of common stock they receive upon conversion of a share of preferred stock are not identical. Overall, the exit payoff per share of preferred stock is closer between senior and junior securities if the startup eventually has an IPO than if it exits via M&As or asset liquidation/sales. In the limit, if the probability of IPO exits (and/or M&A exits with firm valuations comparable to those of IPO exits) is 100%, then it is not unreasonable to assign the same present value for senior and junior securities (aside from the conversion ratio differences, if any).

How mutual funds value the junior securities relative to the model fair value is an open empirical question. On the one hand, it is likely that the negative exit outcome probabilities is not negligible, and thus mutual funds should report lower values for junior securities than senior securities on average. On the other hand, the sample period of 2010-2018 was a period of unprecedented technology sector boom and thus it is possible that mutual funds' expectation for successful exits is quite high, leading them to have a low expected probability of negative outcomes. In such scenarios, we expect them to overvalue the junior securities relative to the model fair values. To the extent that some families hold such beliefs, we expect that the reported junior security values exceed the model fair values on average.

Hypothesis #2: mutual funds value junior securities in excess of the model fair values on average.

We further explore determinants of mutual funds' valuation patterns across both cross-sectional and time-series dimensions. Cross-sectionally, we hypothesize that, consistent with Bayesian updating, fund families with more experience in investing in private startups are either more sophisticated, more knowledgeable, or more realistic about the relative probabilities of successful vs. negative exit outcomes and thus value junior securities closer to their model fair values, whereas fund families with less experience are more naïve or optimistic about the probability of successful exit outcomes and value junior securities closer to the senior security values.

Hypothesis #3a: Fund families with longer investment experience in VC-backed startups value their holdings closer to fair values.

We also hypothesize that fund families with better information cost or access are better at discerning the value differences between senior and junior securities. This is motivated by the fact fund families with better information cost or access are found to be better at updating the values of their private startup investments in the absence of public information about the startup (Agarwal, Barber, Cheng, Hameed, and Yasuda 2023).

Hypothesis #3b: Fund families with better information cost and/or access value their holdings closer to fair values.

We also hypothesize that fund families who purchase private startup securities in secondary transactions are more likely to pay prices higher than the model fair values, and more likely to value them higher than fair values after the initial purchase, each relative to the primary purchasers. There are two distinct reasons as to why we expect this. First, families who are buying private startup securities in secondary transactions lack information access to the issuing firms and therefore lack the information about the complex capital structure needed to discern the value differences between the senior and junior securities. Second, startups whose junior securities fund families seek out in secondary transactions may be those that are expected to go public with a high probability, and therefore fund families believe there is little need to differentiate between the senior and junior securities. We are agnostic as to which reason dominates a priori, and seek to differentiate between the two possibilities by examining the ex post exit outcomes of securities that mutual funds purchase in secondary transactions.

Hypothesis #4a: Fund families pay higher than the model fair values when they purchase junior securities in secondary transactions relative to primary purchasers.

Hypothesis #4b: Fund families report valuation price higher than the model fair values when they purchased the junior securities in secondary transactions relative to primary purchasers.

Across time-series dimension, we hypothesize that fund families Bayesian update their beliefs about the relative probabilities of successful vs. negative exit outcomes after they experience salient events. For example, if a startup has a down round, i.e., a funding round in which the valuation of the firm declines from previous rounds, existing mutual fund investors may increase their expected probability of negative exit outcomes and decrease the probability of successful exit outcomes. If a down round triggers an anti-dilution protection clause and adjustment to conversion ratios (so that a share of preferred is now convertible to more shares of common stock than before), this may further add to the saliency of the negative exit outcome probability and prompting fund families to value junior securities closer to the fair values. Critically, it also differentiates the exit payoff of a share of preferred stock with a conversion ratio greater than 1 from that of a share of preferred stock with a conversion ratio of 1 even in the event of IPO. So even if mutual funds overweight the prospect of an IPO exit, a conversion ratio adjustment may induce a revision in their valuations of affected vs. unaffected securities.

Hypothesis #5a: All else equal, fund families value the junior stakes closer to the model fair values when the startups decide to do a down round.

Hypothesis #5b: All else equal, fund families value the junior stakes closer to the model fair values when the startups decide to do a down round *and* this triggers an anti-dilution clause and an increase in conversion ratios of protected existing investors.

To assess whether the mutual funds' valuations or the model fair values are correct, we investigate whether the ex post performance of mutual fund investments matches their implied expectation of successful exits. We examine if fund families whose portfolio companies will go public in the near future are the ones who hold their junior stakes at par with the senior securities in an anticipatory manner. If they correctly anticipate IPO exits in which senior and junior securities receive the same exit payoff, then their ex ante high valuations are justified ex post.

Hypothesis #6a: Fund families whose portfolio companies go public within 12 months report valuations for their junior stakes more in excess of the model fair values than fund families whose portfolio companies remain private.

Hypothesis #6b: Fund families whose portfolio companies will experience a negative event (e.g., bankruptcy) within 24 months report valuations for their junior stakes closer to the model fair values than fund families whose portfolio companies do not experience negative events.

Other time-series dimensions we plan to explore are (i) cancelled IPOs and (ii) market downturns and declining prospects of IPO exits in 2022. We are currently gathering data necessary for these additional analyses.

Our raw data on mutual fund holdings of private equity securities come from both CRSP Mutual Fund Database and mutual funds' SEC filings of N-CSR and N-Q forms. Because mutual funds' holdings of private equity securities are rare before 2010, we restrict our analyses to holdings reported between 2010 and 2018.

Using the matching method described in Agarwal, Barber, Cheng, Hameed, and Yasuda (2023), we carefully identify 380 securities issued by 242 companies (each security is a unique company-round pair) held by 244 unique mutual funds from 44 fund families. There are two distinct data challenges we face in constructing a clean data set of private equity security holding by mutual funds. First, neither CRSP nor SEC raw data indicate definitively whether a security held by a mutual fund is a private equity security, so we must manually identify and verify private equity securities among mutual fund holdings. We start with a list of VC-backed companies, recently listed companies, and securities without CUSIP reported in the CRSP Mutual Fund database. To identify VC-backed companies, we use Thomson Reuters' One Banker, Genesis, and PitchBook databases. To identify firms that recently went public, we use both Bloomberg and CRSP databases. We then use the company names as keywords to search through mutual funds' SEC filings. For those filings with positive hits, we manually collect holdings information on *all* restricted and illiquid securities. Hence, the private securities in our final sample are not limited to those in the original list.

Second, we must identify the issuer (e.g., Airbnb) and exact Series (A, B, C, etc.) of the security. Assigning the Series to a security turns out to be a non-trivial task because security names are not standardized in mutual fund reports of their holdings. For example, mutual funds frequently only report the security by its issuer name. When compare mutual fund reported valuation to the model fair value, we only use those holdings for which we can identify the series and exclude private security holdings that we cannot clearly assign to a specific round.

Our data on contractual terms of each series, funding history and the capital structure of the private startups come from their Certificate of Incorporation filings with the state in which they are incorporated, Genesis, Pitchbook, Crunchbase, and in case of companies that go public later, their S-1 filings with the SEC. Figure 7 show excerpts from a Certificate of Incorporation filed by Dropbox, Inc. with the state of Delaware.

Table 1 reports the summary statistics for the key variables used as explanatory variables in the empirical analysis. Appendix A provides a detailed definition for each variable.

5. Empirical Results

5.1 Fair Value of Junior and Senior Securities

The per share value of a newly issued security for a private firm at each funding round is reflected in the deal price. However, these prices may not accurately represent the value of securities from earlier series, which have different contractual terms and exit payoffs. Moreover, the newly issued series may have contractual rights that alter the value of junior securities. As indicated in Hypothesis #1, junior claims are expected to be worth significantly less than the latest issued securities.

To test Hypothesis #1 and assess the difference in values of earlier securities compared to new deal prices, we assume that the price paid for newest round of securities is fair and use our option-pricing based model to back-out the fair value of the junior series of the same firm,. Our analysis is based on $DevDeal_{i,j}$ in equation (5), which compares, for each security pair (*i,j*), the deal price of security j (the new funding round security) and the model implied fair price of the earlier round security *i.* at the time when the latest security j is issued.

Table 2 shows the distribution of $DevDeal$. Our sample consists of 65 private firms held by mutual funds which had new funding rounds during the period 2010 to 2018, and covers 214 pairs of securities i and j. Consistent with Hypothesis #1, the fair value of earlier securities is lower than the new deal price as junior securities typically have lower contingent claims on the firm. $DevDeal$ is mostly positive and takes a mean value of 0.63 (median is 0.47). This indicates that the latest-issued senior security is worth 63% higher than the model-implied fair value for earlier securities. When we consider the sub-sample of junior securities purchased by mutual funds in the primary versus secondary markets, the new round prices are 49% higher than fair value for acquisitions in the primary market and twice the fair value for junior securities purchased in the secondary transactions. The considerably larger overvaluation for secondary market purchases can be attributed to the fact that mutual funds buy these from much earlier rounds and therefore have a lower fair value. The median round gap, i.e. the number of rounds between the latest round and the security purchased, is 4 for secondary market purchases and 1 for primary market purchases. These findings support our Hypothesis #1 that the valuations of junior securities are reliably lower than the price of new security issued by startups, particularly for the more junior securities purchased in secondary transactions.

Our assumptions regarding key inputs in the option pricing model are calibrated based on the experience of typical venture-backed private firms. It is important to note these baseline assumptions likely underestimate the valuation differences of senior and junior stakes. Mutual funds likely invest in private companies that are later stage startups, and later stage startups are likely to be less volatile and have shorter expected holding periods than the typical venture-backed private firm. Shorter holding periods and lower volatility would mean bigger differences in the valuation of the senior and junior security. Decreasing our volatility and expected holding period assumptions to comport with the later stage startups preferred by mutual funds would increase the magnitude of the valuation differences that we document.

Another way of addressing the sensitivity of our main results to model inputs is to ask the following question: How much does a model input need to change to close the gap in valuation between a senior and junior stake in the private firm? We consider three key inputs: volatility, expected holding period, and the ratio of the implied enterprise value to the post-money valuation (essentially increasing the assumed enterprise value relative to the purchase price paid in actual deals). For each input, we vary the baseline assumption to reduce the difference between the valuation of the senior and junior stake. Results are presented in Figure 8. On the y axis, we plot the ratio of the senior security value (i.e., the most recent deal price) to the modeled valuation of the average junior stake held by mutual funds. Dots in the figure represent the mean ratio and whiskers depict the interquartile range at a given level of an input variable, which is varied along the x axis.

In Panel A, we analyze volatility. Given the baseline assumption of 90% annual volatility, the senior security is 45% more valuable than the junior security (with an interquartile range of 20.8 to 65.6%). Even at an unrealistically high annual volatility of 150%, the senior security would be 22.4% more valuable than the junior security. Convergence in the value of the junior and senior securities requires annual volatility of the underlying enterprise value of 300%.

In Panel B, we analyze expected holding period where the baseline assumption is an expected holding period of 3 years. Doubling the expected holding period to 6 years reduces the premium on the senior security from 45% but it remains economically large at 26.9%. Even at unrealistically long expected holding periods of 9, 12, and 15 years the senior security remains more valuable than the junior security by 17.8, 11.4, and 7.5% (respectively).

In Panel C, we analyze what happens when we increase the assumed enterprise value. Recall that the senior security deal price allows us to back out the implied enterprise value. The mean ratio of the implied enterprise value to post-money valuation in our baseline analysis is 60% (with an interquartile range of 53 to 68%). If instead we assume the implied enterprise value (unrealistically) equals the post-money valuation, the senior stake would still be worth 27.5% more than the junior stake, on average. The implied enterprise value would need to be more than five times the post-money valuation to close the gap in the valuation of the senior and junior stakes.

In sum, our baseline assumptions are likely conservative and underestimate the true differences in value of junior and senior securities. Moreover, sensitivity analyses summarized in Figure 8 show that volatility, expected holding periods, and enterprise value would need to increase to unrealistic levels to justify parity in the valuation of junior and senior stakes.

To provide further evidence that the reporting similar valuations of junior and senior stakes is represents a valuation error, we analyze a sample of 108 fund family observations where the fund family holds a junior stake and simultaneously holds a senior stake at the time of the funding round for the senior stake. At the time of the senior stake funding round, we use the funding round price to back out an implied enterprise value for the firm (*senior_EV*). At the same point in time, we use the mutual fund's reported price for the junior stake to back out a second implied value (*junior_EV*). To assess the deviation in these prices, we estimate the absolute deviation in the junior and senior values as

$$AbsDev\_EV \;= \left|\frac{senior\_EV}{junior\_EV} - 1\right|. \tag{7}$$

In figure 9, we present a box plot of the distribution of the absolute deviation, which has a mean (and median) of 37% and an interquartile range of 23.1 to 56.3%. These economically large deviations provide further evidence that mutual funds are making a valuation error when they report similar values for junior and senior stakes in a private company.

In the left graph of Figure 10, we plot the exit outcomes of the 238 private companies following the first mutual fund investment in the private company between 2020 and 2018. Exit outcomes are collected from Pitchbook. In this analysis, month 0 is defined as the first mutual fund investment by any mutual fund in our dataset. As a result, month 0 could be associated with a series C investment for one private company but a series G investment for another private company, depending upon when we observe the first mutual fund investment in the private company.

The top line shows the percent of private companies that remain private by month, which steadily declines as (mostly) company's exit via IPO or M&A in the five years following the first mutual fund investment. While IPOs are common for these firms, at the end of five years less than half have gone public (45%) and 15% have exited via M&A deals. Very few firms go bankrupt or liquidate (2%). Thus, 38% remain private at the end of five years.

It is useful to compare these figures to those of typical VC-backed private companies, which we plot in the right graph of Figure 10 using data from 1987 to 2007 from Metrick and Yasuda (2021). These data show that 37% of VC-backed firms remain private five years after the series C investment while 14% go public and 32% exit via an M&A event. Thus, mutual funds appear to select into private companies that equally likely to remain private after five years but are more likely to go public and less likely to be acquired.

5.2 Mutual Fund Valuation of Junior Securities and Fair Value

Our analyses so far indicate that the fair value of junior stakes in startups are significantly lower than the value of newer, senior securities issued by the firm. Next, we examine our Hypothesis #2 on how the prices of these junior securities reported by mutual funds differ from their fair value. If mutual funds take into account the multi-tier capital structure of startups, they are likely to report lower values for junior securities and their reported prices should be close to the fair value. However, mutual funds may report the same (or similar) price for senior and junior securities if they (i) ignore the different contractual features across securities and mechanically update the early round security prices to the latest deal price or (ii) expect the startups to exit via IPOs (or at high values), where all preferred stocks are converted to common stock and are valued equally.

We compare the prices reported by mutual fund family F for their holdings of junior private securities (security i) relative to the model-implied fair values at the time of a newer round of security issuance (security j) at time t_j, as defined by $DevPrc_{Fit_j}$ in equation (6). The unit of analyses is at family-security-pair level as there is no dispersion in prices for the same security across funds within the same family (Agarwal, Barber, Cheng, Hameed, and

Yasuda (2023)). Panel A of Table 3 presents the distribution of *DevPrc* for the 214 security pairs reported by 40 fund families. The average (median) *DevPrc* is 0.68 (0.42), which means that mutual fund families report prices of junior securities that are 68% (42%) higher than their fair values. Since the average difference between deal prices and fair values is 62%, according to Table 2, the results suggest that mutual funds mark the junior securities close to the value of the recently issued senior securities. This valuation practice applies to both primary and secondary market purchases. The overvaluation of junior securities is 43% for primary market acquisitions and increases dramatically for the securities purchased in the secondary markets. Mutual fund families report prices that are more than twice the model implied fair values for secondary market purchases, with mean *DevPrc* of 1.39. Overall, the evidence suggests that mutual funds ignore valuation differences and value junior securities close to the new security prices.

To shed more light on the secondary market purchases, we examine whether fund families pay higher than the model fair values when they purchase junior securities in secondary transactions relative to primary acquisitions (Hypothesis #4a). In Panel B of Table 3, we present the valuation difference between the family's first reported price and the model-implied fair values at the time the mutual fund purchased the security. The model-implied fair values are derived from the deal price of the latest funding round. In cases where the security is purchased in the primary market, the fair value is the new round deal price and the reported values are expected to be close to the fair value.[6] As expected, $DevPrc$ is close to zero for securities purchased in the primary market. However, consistent with Hypothesis #4a, we find that reported prices for secondary market purchases of junior securities display the same magnitude of overvaluation relative to fair value as in Panel A. Unlike private securities acquired at issuance, the secondary transactions are overpriced. These findings suggest that mutual funds report junior security prices that are overvalued which may be associated with the expectation of eminent IPO exits (where all securities are likely to be equally valued) and an underestimation of the probability of exits with a low enterprise value (where these securities have unequal exit payoffs).[7] We investigate these alternative explanations in subsection 5.4.

[6] Any deviation in prices from fair value reflect updating in the reported prices for information between the funding round date and reporting date in the same quarter, or a liquidity discount applied by some fund families (see Agarwal et al (2023)).

[7] Private conversations with practitioners indicate that buyers in (informal) secondary markets, often request private securities by startup name but not by specific series, and use recent deal price of the senior security as a reference price point.

5.3 Determinants of the difference in mutual fund valuations relative to model-implied fair values

In this section, we investigate the potential explanations for the valuation difference between a fund family's reported price and the model-implied fair value of an early round security at the time of the new round. Specifically, we test four hypotheses: (i) fund families with longer investment experience in private companies value their holdings closer to fair values (Hypothesis #3a); (ii) fund families with better information cost and/or access value their holdings closer to fair values (Hypothesis #3b); (iii) fund families report valuation price higher than the model fair values when they purchased the junior securities in secondary transactions relative to primary purchasers (Hypothesis #4b); (iv) fund families value the junior stakes closer to the model fair values when the startups decide to do a down round (Hypothesis #5a); and (v) fund families value the junior stakes closer to the model fair values when the startups decide to do a down round and this triggers an anti-dilution clause and an increase in conversion ratios of protected existing investors (Hypothesis #5b).

To this end, we estimate the following OLS regression:

$$DevPrc_{F,i,j} = \alpha + \beta_1 Char_{F,i,j} + \gamma M_{F,i,j} + \varepsilon_{F,i,j}, \quad (8)$$

where $DevPrc_{F,i,j}$ is the valuation difference between fund family F's reported price and the model-implied fair value of an early round security i at the time of the new round j; $Char_{F,i,j}$ is a vector of family, security, and family-security characteristics, including *Ln(PE Experience)*, *Ln(PE Value)*, *%Firm Round Size*, *%Firm Round Size-Early*, *%Firm Round Size-New*, *Firm Weight*, *Down Round Adjustment*, and *Down Round*. The vector *M* stacks all other control variables, including *Secondary*, *Round Gap*, and *Reporting Gap*. We control for *Round Gap* to account for more junior securities typically having lower fair value (therefore greater overvaluation), and *Reporting Gap* to account for valuation differences because of different reporting cycles of funds (gap can be up to two months as funds can report in month T+2 for a new round in month T). We cluster the standard errors by new round.

Our findings reported in Table 4 support three of the four hypotheses. In all the three specifications (models 1, 8, and 9) where we include *Ln(PE Experience)* as a covariate, its coefficient is negative and significant. This finding is consistent with Hypothesis #3a and suggests that fund families with longer experience of private company investments value early round securities closer to model-implied fair values. Experience of prior investing in private securities has an economically significant effect on bridging the difference in the fund family's valuation of junior securities and fair value. A one standard deviation increase in *Ln(PE Experience)* is associated with a decrease of 15.7% in the valuation difference, $DevPrc_{F,i,j}$.[8] In contrast, we do not find evidence in support of Hypothesis #3b. We proxy the information costs with the private equity exposure, *Ln(PE Value)*, of fund families and access to information with a fund family's stake in a funding round, *%Firm Round Size*. Although the coefficients on both these proxies are negative in model 2, they are not statistically significant. Breaking down the fund family's stake into early round (*%Firm Round Size-Early*) and the new round (*%Firm Round Size-New*) securities shows that latter seems to have a statistically stronger effect on valuation difference, but the coefficients are not significant at conventional levels (coefficient of -0.429 with a *t*-stat of -1.31 in model 3 and coefficient of -0.506 with a *t*-stat of -1.52 in model 9).

We observe strong support for Hypothesis #4b. The coefficient on *Secondary* is positive and significant at the 1% level in all specifications indicating that fund families overvalue the junior securities purchased in secondary transactions. Overvaluation is economically large ranging from about 102% to 111% across specifications. Finally, we also find evidence consistent with Hypotheses #5a and #5b. The coefficient on *Down Round* is consistently negative and strongly significant in models 6 through 9. This suggests that fund families value the junior securities closer to the model fair values in case of down rounds (Hypothesis #5a). The valuation difference shrinks significantly ranging from about 28% to 42% during down rounds. Furthermore, when a down round triggers an anti-dilution clause and an increase in conversion ratios of protected existing investors, fund families also value the junior securities closer to the model fair values (Hypothesis #5b). Specifically, the coefficients on *Down Round Adjustment* are negative and significant, indicating a decline in overvaluation by 36% to 40% (models 5 and 7 through 9).

5.4 Mutual fund valuation and exit events of private firms

In this section, we examine if mutual funds value junior securities closer to the model fair values hence display less overvaluation (closer to the senior security values hence display more overvaluation) when they anticipate a higher (lower) likelihood of negative exit outcomes

[8] We compute the economic magnitude as $-0.290\times0.540 = 15.7\%$, where 0.290 is the regression coefficient in model 1, 0.540 is the standard deviation of *Ln(PE Experience)* (Table 1).

where senior securities get paid more per share than junior securities. Specifically, we consider two salient exit events: (i) a positive future outcome such as an initial public offering (IPO) (Hypothesis #6a) and (ii) negative events such as bankruptcy and cancellation of IPOs (Hypothesis #6b). We test the "timing" of such overvaluation by mutual funds by estimating the following OLS regression:

$$DevPrc_{F,i,j} = \alpha + \beta_1 Exit_{i,j} + \gamma M_{F,i,j} + \varepsilon_{F,i,j}, \qquad (9)$$

where $DevPrc_{F,i,j}$ is the valuation difference between fund family F's reported price and the model-implied fair value of an early round security i at the time of the new round j. $Exit_{i,j}$ is a vector of security characteristics, including *Future IPO* and *Future Negative Events*. The vector *M* stacks all other control variables, including *Secondary*, *Round Gap*, and *Reporting Gap*. We cluster the standard errors by new round.

There are three notable findings in Table 5. First, we observe a significantly negative relation between a fund family's overvaluation and the private firm going public within the next twelve months of the new round (models 1, 3, 4, and 6). This result is striking because it does not support Hypothesis #6a that funds overvalue junior securities in anticipation of a firm's successful exit with a public offering, which would have predicted a positive relation between mutual fund overvaluation and future IPO exit. Second, we do not find any evidence in support of Hypothesis #6b that mutual fund families adjust their value of junior securities downwards in anticipation of negative outcomes in the future such as the firm going bankrupt or cancelling its IPO (models 2, 3, 5, and 6). Third, we continue to find strong support for Hypothesis #4b, confirming our previous findings in Table 4. The coefficient on *Secondary* is positive and significant at the 1% level in models 4 through 6 with similar magnitude as in Table 4, indicating that fund families overvalue the junior securities purchased in secondary transactions.

5.5 Naïve/Optimistic Overvaluation vs. Strategic Inflation

The results presented so far are consistent with mutual fund investors naively overweighting the probability of successful exit outcomes while underweighting the probability of poorer outcomes. An alternative explanation is that mutual funds knowingly and strategically inflate the reported values junior securities they hold. We already present in

Table 3, Panel B that mutual funds' first reported values of junior securities purchased in secondary transactions are higher than their model fair values, suggesting they overpaid for them. Overpayment is inconsistent with strategic inflation. In Table 3, Panel B, we inferred that the first reported values of these junior securities are equal to or close to the price they paid to purchase them, since the purchase has to have occurred within a quarter of the reporting date, and there is little room for mutual funds to change their values within a quarter. To rule out any possibilities that mutual funds changed the reported values between the original purchase date and the reporting date, we also examine instances where mutual funds explicitly report their acquisition cost in their N-CSR and N-Q filings. Examples of these purchases are reported in Figure 11.

As shown here, mutual funds pay prices far in excess of model fair values for junior securities around the time of the latest senior security issuance date, which is consistent with naïve or optimistic valuation and inconsistent with strategic inflation. The acquisition cost is often identical to or near the original purchase price of the latest senior security. For example, at the time of the senior security Series G issuance at $16.09 per share by Twitter, its Series A preferred had a model fair value of $8.62 per share. Despite this large difference in fair values, T. Rowe Price Growth Stock Fund purchased the Series A preferred around the time of Series G issuance at $16.13, thus paying 87% above the fair value (($16.13-$8.62)/$8.62). We believe that these transactions provide compelling anecdotal evidence that mutual funds are making naïve or optimistic valuation errors, as opposed to knowing and strategically inflating reported values of junior securities.

5.6 Aggregate Misvaluation by Mutual Funds

In this section we construct a quarterly times series measure of aggregate misvaluation of private startup stakes by mutual funds. At the individual security level, misvaluation is measured by $DevPrc_{Fit_j}$, as defined in Equation (6). In a given quarter, we aggregate both the reported values and fair values of all the junior stakes held by mutual funds $F = 1, \ldots, F_N$. The aggregate misvaluation at time *t* by fund families is given by

$$AggDevPrc_t = \frac{\sum_F \sum_i q_{Fit} \times Price_{Fit}}{\sum_F \sum_i q_{Fit} \times Fair\ Value_{i\,t}} - 1, \qquad (10)$$

where q_{Fit} equals the number of shares of junior security *i* held by fund family F in quarter *t*, $Price_{Fit}$ is the value per share for security *i* reported by fund family F in quarter *t*, and *Fair*

$Value_{it}$ is the model fair value for security *i* in quarter *t.* Note that in all prior analyses, we always back out the fair value of junior security only at the time of the issuance of a senior security by the same startup. For the aggregate misvaluation measure, we wish to have a fair value for security *i* continuously each quarter. However, startups raise a new series of security on average once every 6 quarters (Agarwal, Barber, Cheng, Hameed, and Yasuda (2023)). Thus, we have a sparsity problem. We address this issue in two alternative ways. In the first method we call the Stale Price method, we continue to use the fair value of a junior security *i* obtained at the time of a senior security *j*'s issuance t_j each quarter until a subsequent senior security *k* is issued, or the startup has a liquidation event and the private security *i* is removed from the fund's portfolio. For this method, we replace $Fair\ Value_{it}$ in Equation (10) with $Fair\ Value_{i,t_j}$. Similarly, we replace $Price_{Fit}$ in Equation (10) with $Price_{i,t_j}$. While this method has the advantage of only using fair values backed out from arm's length transactions (VC funding rounds where outside investors pay a price to purchase a security from a startup), one drawback is that both the reported value and the fair value becomes stale between senior security funding rounds.

In the second method we first calculate the average valuation for the senior security *j* at quarter *t* held by all mutual fund families. Suppose this is \$5 in quarter *t*. Then, using \$5 as the assumed fair value for security *j,* we back out the implied value of the firm and then the implied fair value of the junior security *i* in quarter *t.* We label the pseudo-fair value of junior security *i* backed out in this way $Fair\ Value_{i,t,F_j}$. It is a pseudo-fair value in the sense that we rely on mutual funds collectively to report the senior security *j* at fair value on average each quarter. Since we document quite extensively that mutual funds deviate from fair value reporting when it comes to junior security, we are not confident that they report the senior security at fair value, either, once that initial quarter in which the security is issued passes. Nonetheless, we use this method because it allows us to back out the fair value of junior security on a relative basis (if not on absolute basis), and it allows us to update its value between senior security rounds.

The results are reported in Table 6. Note that we start the aggregate measure in the first quarter of 2014 when the number of investments (65) and the aggregate dollar amount invested (\$575 million) reach a critical mass. With the method using stale fair values, the aggregate misvaluation averages 39%, with an inter-quartile range of 37% and 42%. With the method using family-reported prices, the aggregate misvaluation averages 44%, with an inter-quartile range of 34% and 50%. In terms of absolute dollar amount, in the 3rd quarter of 2018, the total junior securities held by mutual funds were reported to be worth about $7.1 billion, whereas the fair values for these holdings were worth about $4.8 billion. Suppose that the "true" portfolio weight of private startups at fund A was 5%, or $5M, but it was reported to be worth $7M (40% overvaluation). If this misvaluation were corrected one day, and the holding value goes down to $5M, then that represents 40%*5% = 2% loss of the overall fund portfolio value. While this seems small, note that Silicon Valley Bank's loss from the long-term bond sale was only $1.8B against its total balance sheet size of $209B, and yet that was sufficient to cause a bank run.

6. Conclusion

In this paper we study mutual fund families' reported valuation of private startup stakes they hold in their open-ended mutual funds. Since these reported values are used to calculate the fund Net Asset Values daily, misvaluation of illiquid securities by fund families results in wealth transfers from buyers and sellers of fund shares. Since open-ended mutual funds must meet liquidity demands from investors, overstated reported value and unrealized loss on illiquid security holdings by mutual funds could generate financial fragility and a potential run on the funds. This potential mismatch between the illiquid, hard-to-value private startup stake and the liquidity demand by end investors motivates our study.

We first analyze complex and opaque contracts that govern the multi-tier capital structure of private startups by applying an option-pricing based model and estimate implied fair value of junior securities relative to the most senior security that is assumed to be issued at par. We find that on average the senior preferred stock is worth 48% more than the junior preferred stocks that mutual funds hold at the time of the senior security issuance. These results are robust to a host of sensitivity analysis.

Yet, we find that mutual funds report their junior stakes at 43% higher than the fair values, i.e., close to par with the senior preferred stock. Under uncertainty of exit timing and exit values and given the contingent exit payoffs for each security as a function of enterprise values at exit, it is difficult to rationalize common practice where two securities are held at the same price at the same time by the same mutual fund family. We show that beliefs that fund families need to have about underlying stock and investment characteristics to rationalize assigning identical values to senior and junior securities are either implausible or unlikely to be the assumptions held by mutual fund investors.

We find that valuation is closer to fair values for fund families with longer experience in private startup investments, and more aggressive (closer to the senior security value) when securities are purchased in secondary transactions. Valuation becomes closer to fair values after down rounds and conversion ratio adjustments, after which even post-conversion values of senior and junior preferred stock are no longer equal. The results are not driven by firms on the cusp of IPOs and are not justifiable by the ex-post probability of successful exits. Taken together, the results suggest that mutual funds overweight the probability of successful exits where all securities convert to common and downplay the probability of negative outcomes where junior securities are paid less. This may become costly errors in market downturns where negative exit outcomes become more likely for the private startups, and/or investors start demanding liquidity from funds holding junior stakes in these startups and valuing them at the same price as the senior security.

We are agnostic as to whether our findings are generalizable to how VC funds report valuations of their security-level holdings to their limited partner investors, or what impact the mutual funds' valuation practice has on VCs' performance. Such data are not publicly available at the level of individual securities they hold. One critical difference is that VC funds are closed-end; thus, interim misvaluation is less consequential, since LPs cannot demand withdrawal. Since the non-traditional investors contribute significant portions of total invested dollar amounts in VC-backed private startups in recent years, it is likely that their valuation practice has a non-trivial impact on the VCs themselves. For example, on the one hand, if non-traditional investors overweight the probability of successful exit outcomes and that drives up the valuations of startups, that reduces good investment opportunities for traditional VCs. On the other hand, if non-traditional investors are willing buyers of early-series securities in the secondary market, then that creates a potentially attractive new exit opportunity for VCs and private startup employees.[9] These are potential avenues for future research.

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[9] In private conversations with secondary market specialists, we learned that sometimes buyers in the secondary markets agree to a transaction with a set price per share even without knowing which series of preferred they are buying, or if they are buying preferred or common.

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Appendix A: Variable Definitions

Variables	Definitions
DevDeal	Let i and j stand for securities issued in an early round and a new round within the same firm, respectively. The valuation difference between the new round deal price and the fair value of an early round security at the time of security j's issuance t_j is computed as follows: $DevDeal_{i,t_j} = \frac{Deal\ Price_j}{Fair\ Value_{i,t_j}} - 1$, where $Deal\ Price_j$ is the deal price per share of the security issued in the new round j, and $Fair\ Value_{i,t_j}$ is the model-implied fair value per share of an early round security i at the time of the new round j.
DevPrc	Let i and j stand for securities issued in an early round and a new round within the same firm, respectively. The valuation difference between mutual fund family F's reported price and the fair value of an early round security at the time of security j's issuance t_j is computed as follows: $DevPrc_{F,i,t_j} = \frac{Price_{F,i,t_j}}{Fair\ Value_{i,t_j}} - 1$, where $Price_{F,i,t_j}$ is the value per share for an early round security i reported by fund family F at the time of the new round j, and $Fair\ Value_{i,t_j}$ is the model-implied fair value of an early round security i at the time of the new round j. When $Price_{F,i,t_j}$ is not available at the same month of new round issuance, we employ the first reported price within three months after the new round.
AggDevPrc	The aggregate misvaluation by fund families in a given quarter t is computed as follows: $AggDevPrc_t = \frac{\text{MF Value}_t}{\text{Fair Value}_t} - 1 = \frac{\sum_F \sum_i q_{F,i,t} \times Price_{F,i,t}}{\sum_F \sum_i q_{F,i,t} \times Fair\ Value_{i,t}} - 1$, where MF Value_t and Fair Value_t are the total reported values and fair values of all the junior stakes held by mutual funds, respectively. $q_{F,i,t}$ is the number of shares of junior security i held by fund family F in quarter t, $Price_{F,i,t}$ is the value per share for security i reported by fund family F in quarter t, and $Fair\ Value_{i,t}$ is the model-implied fair value for security i in quarter t. We obtain the fair value of a junior security in two ways. First, we obtain the fair value of a junior security at the time of a senior security j's issuance (assume that the price paid for the newest round of securities is fair) and keep the fair value unchanged until a subsequent senior security k is issued (stale price method). Second, we assume that fund families collectively report the senior security j at fair value, and back out the fair value of a junior security in each quarter (family reported price method). If mutual funds do not invest in the senior security j, we use the fair value of a junior security obtained at the time of a senior security j's issuance.

Ln(PE Experience)	The logarithm of the number of quarters since the first private equity investment by a family.
Ln(PE Value)	The logarithm of the total dollar amount of private firms in the family's portfolio.
%Firm Round Size	The total dollar amount of each private firm in a family's portfolio, scaled by the total deal size of the corresponding funding rounds.
%Firm Round Size-Early	The total dollar amount of all early round securities in a private firm in a family's portfolio, scaled by the total deal size of the corresponding funding rounds.
%Firm Round Size-New	The total dollar amount of the new round security in a private firm in a family's portfolio, scaled by the deal size of the new round.
Firm Weight	The percentage weight of each private firm in a family's total equity portfolio before the new round.
Down Round Adjustment	An indicator variable that equals one if early round security requires a down round adjustment to conversion price and zero otherwise.
Down Round	An indicator variable that equals one if the deal price of the new round is lower than that of the previous round and zero otherwise.
Secondary	An indicator variable that equals one if a family purchases the private security at least six months after its issuance and zero otherwise.
Round Gap	The number of funding rounds between an early round and the new round.
Reporting Gap	The number of months between the new round issuance and the reporting time of a family.
Future IPO	An indicator variable that equals one if the firm completes an initial public offering (IPO) within 12 months after the new round and zero otherwise.
Future Negative Events	An indicator variable that equals one if the firm goes bankrupt, goes out of business, or cancels IPO within 24 months after the new round and zero otherwise.

Table 1: Summary Statistics

This table presents the summary statistics for the data used in the paper during the period from 2010 to 2018. We report the means, standard deviations, medians, and quantile distribution of mutual fund family, security, and family-security characteristics. Appendix A provides a detailed definition for each variable.

	Mean	Std.Dev.	10%	25%	Median	75%	90%
Ln(PE Experience)	2.870	0.540	2.079	2.565	2.996	3.258	3.466
Ln(PE Value)	5.116	2.525	1.478	2.662	5.463	7.362	8.404
%Firm Round Size	0.113	0.177	0.001	0.005	0.043	0.141	0.323
%Firm Round Size-Early	0.112	0.176	0.001	0.003	0.042	0.152	0.321
%Firm Round Size-New	0.024	0.095	0.000	0.000	0.000	0.000	0.055
Firm Weight	0.295	0.371	0.038	0.085	0.174	0.357	0.730
Down Round Adjustment	0.024	0.153	0	0	0	0	0
Down Round	0.036	0.186	0	0	0	0	0
Secondary	0.141	0.348	0	0	0	0	1
Round Gap	2.153	1.378	1	1	2	3	4
Reporting Gap	0.788	0.827	0	0	1	2	2

Table 2: Fair Value Differences

For each security pair, we compute the valuation difference between the new round deal price and the model-implied fair value of an early round security at the time of the new round (*DevDeal*). This table reports the number of firms and security pairs as well as the summary statistics for *DevDeal*, in the full sample and subsamples for primary and secondary market purchases. Appendix A provides a detailed definition for each variable.

Sample	No. Firm	No. Security Pair	Mean	Std.Dev.	10%	25%	Median	75%	90%
All	65	214	0.629	0.833	0.000	0.167	0.473	0.822	1.198
Primary	61	167	0.485	0.796	-0.001	0.133	0.357	0.617	1.011
Secondary	19	59	1.030	0.759	0.470	0.638	0.844	1.198	2.192

Table 3: Mutual Fund Valuation Relative to Fair Value

In Panel A, for each family-security-pair, we compute the valuation difference between fund family's reported price and the model-implied fair value of an early round security at the time of the new round (*DevPrc*). We report the number of firms, security pairs, families, and family-security pairs, as well as the summary statistics for *DevPrc*, in the full sample and subsamples for primary and secondary market purchases. Panel B reports similar statistics at the time of purchase, i.e., the valuation difference between the family's first reported price and the model-implied fair value at that time (based on the latest funding round). Appendix A provides a detailed definition for each variable.

Sample	No. Firm	No. Security Pair	No. Family	No. Family-Security Pair	Mean	Std.Dev.	10%	25%	Median	75%	90%
Panel A: At the Time of a New Round											
All	65	214	40	520	0.678	1.131	-0.055	0.106	0.424	0.775	1.437
Primary	61	167	39	387	0.433	1.077	-0.140	0.027	0.282	0.499	0.699
Secondary	19	59	19	133	1.389	0.973	0.437	0.696	1.190	1.521	3.101
Panel B: At the Time of Purchase											
All	54	123	37	305	0.497	0.856	-0.005	0.000	0.000	1.021	1.362
Primary	52	77	36	193	0.031	0.224	-0.082	0.000	0.000	0.000	0.003
Secondary	20	46	19	112	1.300	0.944	0.478	0.719	1.190	1.365	3.557

Table 4: Determinants of Mutual Fund Overvaluation

This table presents the results of the following OLS regressions and the corresponding *t*-statistics with standard errors clustered by the new round:

$DevPrc_{F,i,t_j} = \alpha + \beta_1 Char_{F,i,t_j} + \gamma M_{F,i,t_j} + \varepsilon_{F,i,t_j}$,

where $DevPrc_{F,i,t_j}$ is the valuation difference between fund family F's reported price and the model-implied fair value of an early round security i at the time of the new round j. $Char_{F,i,t_j}$ is a vector of family, security, and family-security characteristics, including *Ln(PE Experience)*, *Ln(PE Value)*, *%Firm Round Size*, *%Firm Round Size-Early*, *%Firm Round Size-New*, *Firm Weight*, *Down Round Adjustment*, and *Down Round*. The vector *M* stacks all other control variables, including *Secondary*, *Round Gap*, and *Reporting Gap*. Appendix A provides a detailed definition for each variable. *, **, and ***, significant at the 10%, 5%, and 1% level (respectively).

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Ln(PE Experience)	-0.290*							-0.311*	-0.321*
	(-1.82)							(-1.72)	(-1.71)
Ln(PE Value)		-0.017	-0.021					0.021	0.017
		(-0.78)	(-0.92)					(1.18)	(0.96)
%Firm Round Size		-0.111						-0.089	
		(-0.41)						(-0.33)	
%Firm Round Size-Early			0.047						0.128
			(0.17)						(0.43)
%Firm Round Size-New			-0.429						-0.506
			(-1.31)						(-1.52)
Firm Weight				0.217*				0.125	0.119
				(1.81)				(1.44)	(1.38)
Down Round Adjustment					-0.398**		-0.372**	-0.356*	-0.366*
					(-2.28)		(-2.00)	(-1.70)	(-1.85)
Down Round						-0.417***	-0.400***	-0.282***	-0.282***
						(-3.35)	(-2.98)	(-3.29)	(-2.96)
Secondary	1.018***	1.079***	1.076***	1.114***	1.048***	1.046***	1.038***	1.027***	1.018***
	(3.36)	(3.38)	(3.37)	(3.51)	(3.32)	(3.27)	(3.28)	(3.27)	(3.24)
Round Gap	-0.014	-0.033	-0.032	-0.044	-0.026	-0.030	-0.027	-0.020	-0.017
	(-0.30)	(-0.66)	(-0.64)	(-0.78)	(-0.50)	(-0.56)	(-0.52)	(-0.46)	(-0.39)
Reporting Gap	0.050	0.021	0.022	0.037	0.039	0.028	0.028	0.054	0.057
	(0.91)	(0.33)	(0.35)	(0.65)	(0.69)	(0.48)	(0.48)	(0.84)	(0.88)
Constant	1.177**	0.504*	0.509*	0.343**	0.386**	0.409**	0.412**	1.134*	1.163*
	(2.03)	(1.91)	(1.91)	(2.06)	(2.20)	(2.26)	(2.27)	(1.94)	(1.92)
Obs	419	419	419	419	419	419	419	419	419
R-squared	0.165	0.142	0.144	0.146	0.143	0.145	0.149	0.177	0.180

Table 5: Mutual Fund Overvaluation and Exit

This table presents the results of the following OLS regressions and the corresponding *t*-statistics with standard errors clustered by the new round:

$DevPrc_{F,i,t_j} = \alpha + \beta_1 Exit_{i,t_j} + \gamma M_{F,i,t_j} + \varepsilon_{F,i,t_j}$,

where $DevPrc_{F,i,t_j}$ is the valuation difference between fund family F's reported price and the model-implied fair value of an early round security i at the time of the new round j. $Exit_{i,t_j}$ is a vector of security characteristics, including *Future IPO* and *Future Negative Events*. The vector *M* stacks all other control variables, including *Secondary*, *Round Gap*, and *Reporting Gap*. Appendix A provides a detailed definition for each variable. *, **, and ***, significant at the 10%, 5%, and 1% level (respectively).

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Future IPO	-0.425**		-0.426**	-0.404**		-0.391**
	(-2.19)		(-2.10)	(-2.47)		(-2.39)
Future Negative Events		0.026	-0.010		0.230	0.201
		(0.07)	(-0.03)		(0.61)	(0.54)
Secondary				1.042***	1.077***	1.074***
				(3.77)	(3.76)	(3.82)
Round Gap				-0.063	-0.073	-0.072
				(-1.19)	(-1.33)	(-1.32)
Reporting Gap				0.020	0.022	0.012
				(0.20)	(0.21)	(0.12)
Constant	0.696***	0.661***	0.697***	0.566***	0.530***	0.571***
	(4.61)	(4.40)	(4.30)	(2.80)	(2.80)	(2.85)
Obs	511	511	511	511	511	511
R-squared	0.010	0.000	0.010	0.142	0.135	0.144

Table 6: Aggregate Misvaluation by Mutual Funds

This table presents the aggregate misvaluation by mutual funds over time. In a given quarter, we aggregate both the reported values ($MF\ Value$, in $Mn) and fair values ($Fair\ Value$, in $Mn) of all the junior stakes held by mutual funds, and compute the aggregate misvaluation ($AggDevPrc$) as $MF\ Value / Fair\ Value - 1$. We obtain the fair value of a junior security (i) at the time of a senior security's issuance (assume that the price paid for the newest round of securities is fair) and keep the fair value unchanged until a subsequent senior security is issued (stale price method), and (ii) in each quarter by assuming that fund families collectively report the senior security at fair value (family reported price method). Appendix A provides a detailed definition for each variable.

Date	No. Family-Security Pair	Stale Price AggDevPrc	Stale Price MF Value ($Mn)	Stale Price Fair Value ($Mn)	Family Reported Price AggDevPrc	Family Reported Price MF Value ($Mn)	Family Reported Price Fair Value ($Mn)
20140331	65	0.523	589	387	0.684	575	341
20140630	82	0.296	1,090	841	0.288	1,024	795
20140930	84	0.311	1,154	880	0.321	1,089	824
20141231	93	0.356	2,310	1,704	0.343	2,274	1,693
20150331	101	0.382	2,601	1,882	0.431	2,614	1,827
20150630	137	0.292	3,529	2,731	0.336	3,519	2,634
20150930	151	0.326	4,061	3,061	0.435	4,272	2,976
20151231	151	0.427	7,309	5,123	0.515	4,832	3,190
20160331	156	0.414	7,085	5,010	0.489	4,386	2,945
20160630	163	0.405	7,652	5,446	0.497	5,062	3,380
20160930	172	0.404	8,101	5,771	0.515	5,601	3,697
20161231	171	0.411	8,254	5,851	0.542	5,691	3,691
20170331	152	0.411	8,025	5,686	0.551	5,628	3,628
20170630	143	0.407	5,523	3,926	0.498	5,392	3,600
20170930	150	0.415	5,544	3,917	0.495	5,384	3,600
20171231	157	0.431	5,601	3,915	0.371	4,846	3,535
20180331	155	0.418	5,567	3,925	0.211	4,854	4,007
20180630	145	0.416	6,710	4,738	0.341	6,201	4,625
20180930	145	0.410	6,993	4,958	0.482	7,070	4,770
20181231	147	0.370	5,093	3,719	0.405	4,907	3,492

Figure 1: Exit Diagram of a 30% Equity Owner

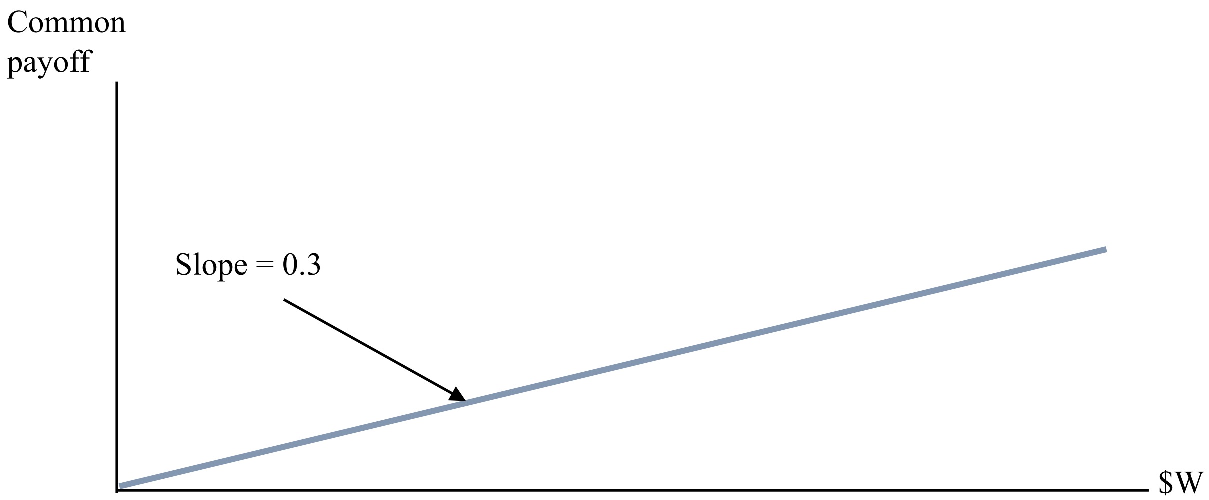


Figure 2: Exit Diagrams

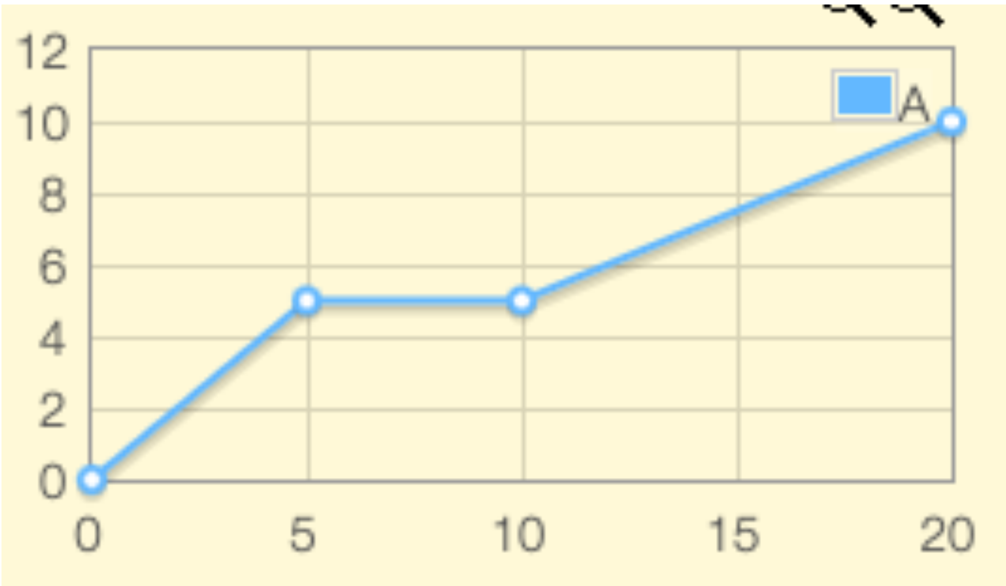


Figure 2a. Exit Diagram for Series A

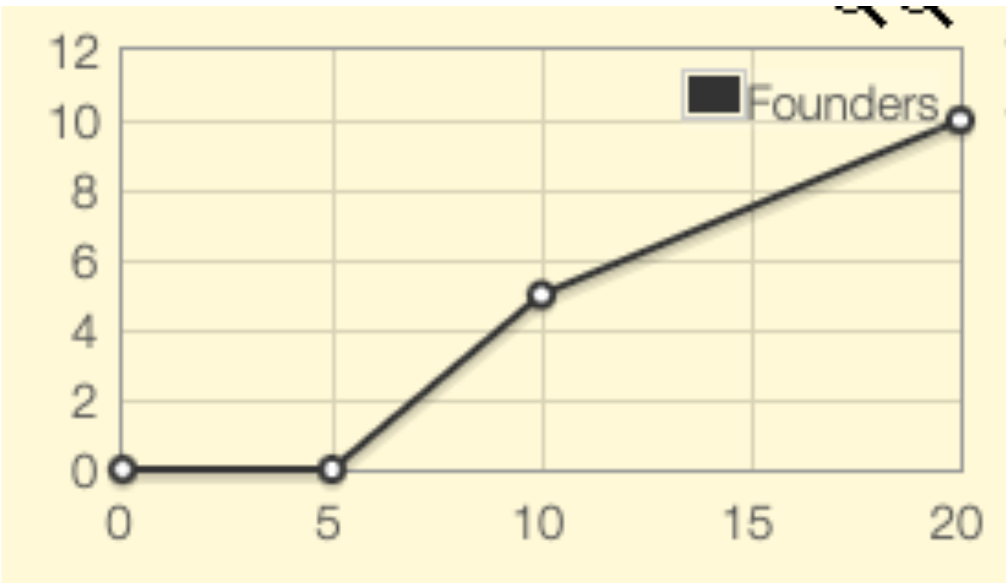


Figure 2b. Exit Diagram for Founders

Figure 3: Exit Diagram for Founders as a Call Option-like Claim

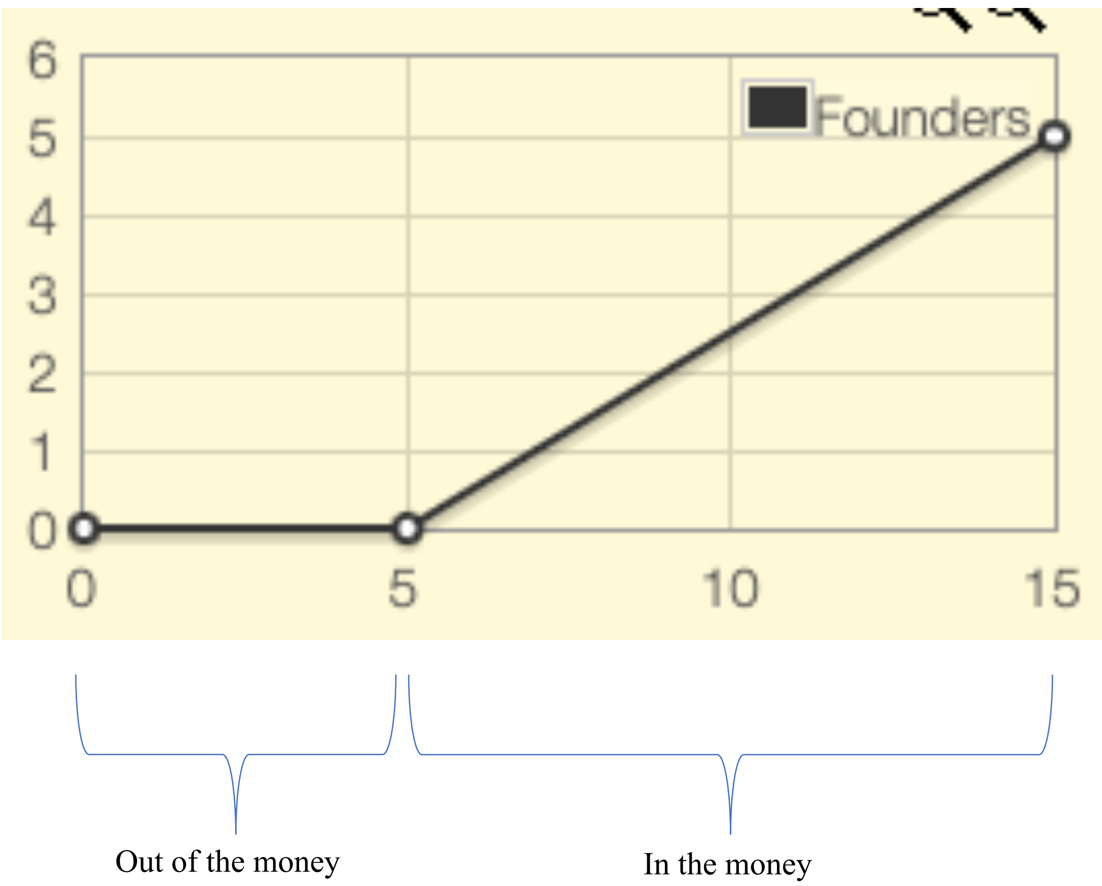


Figure 4: Multi-round Example with Series B

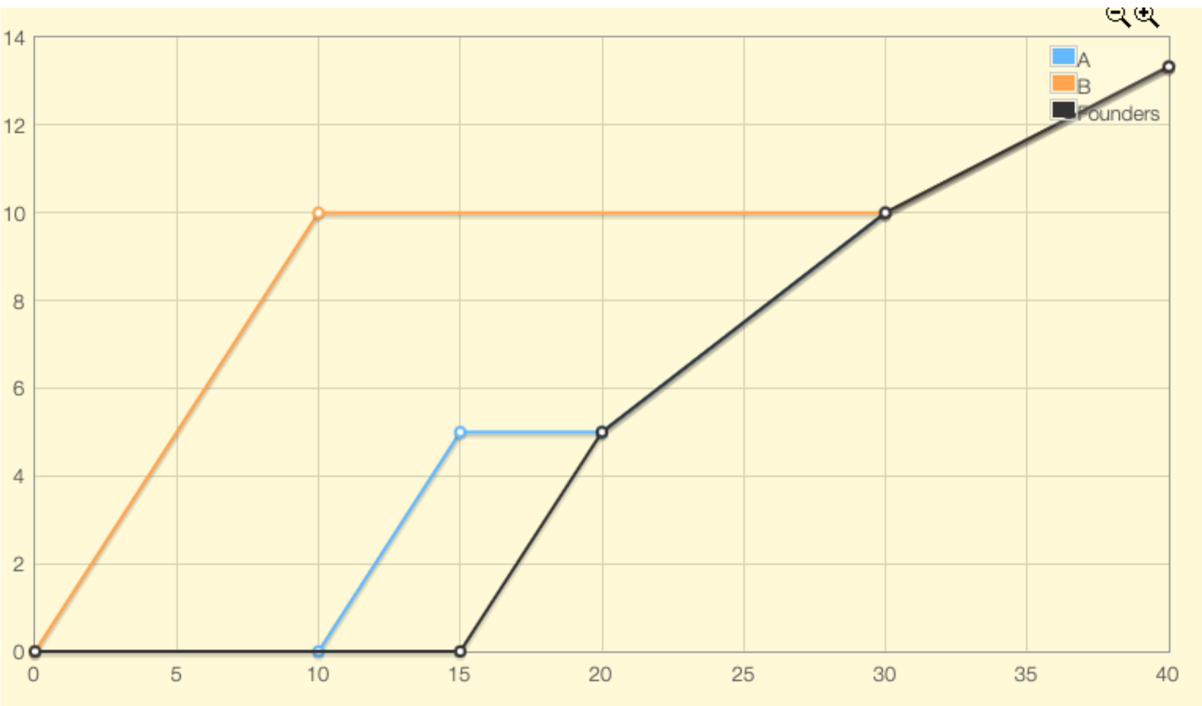


Figure 5: Participation and Forced Conversion to Common at IPO

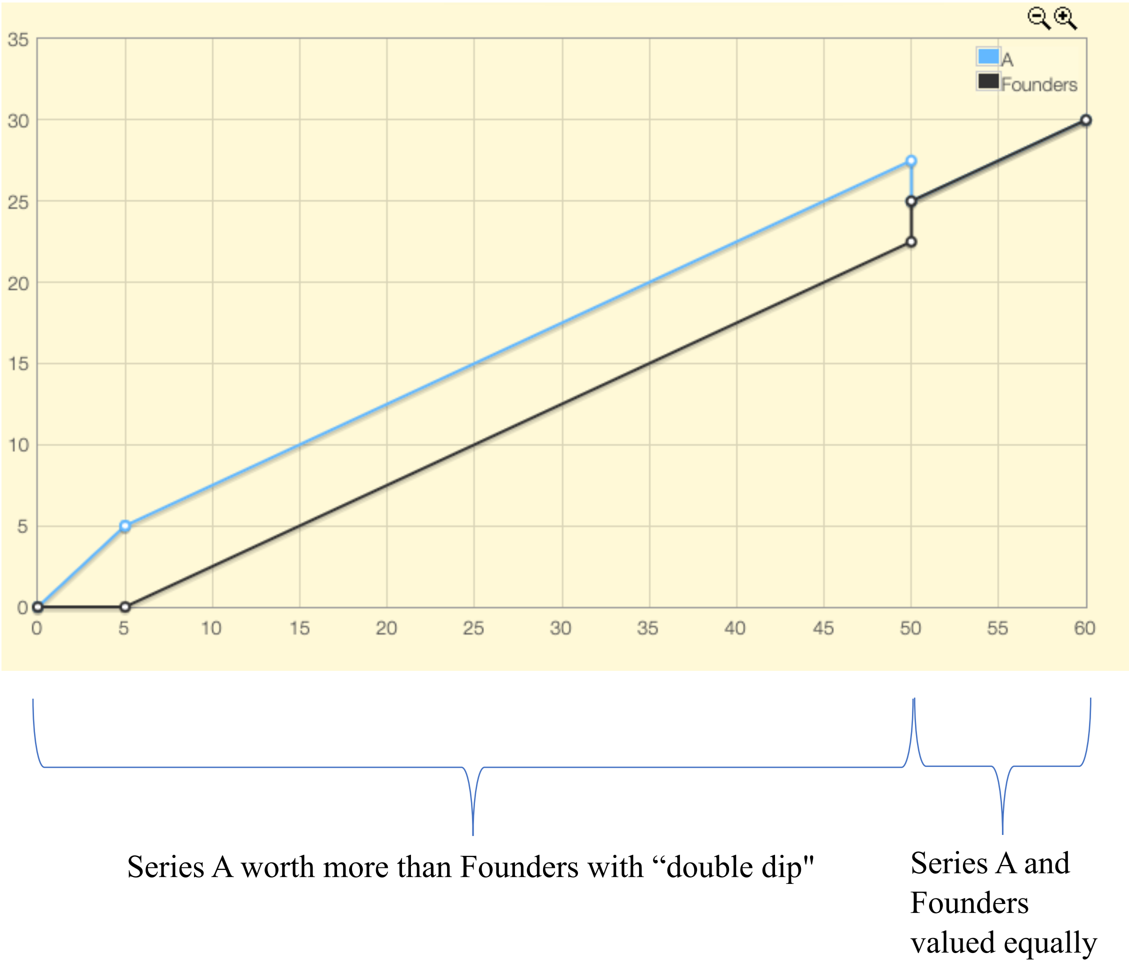
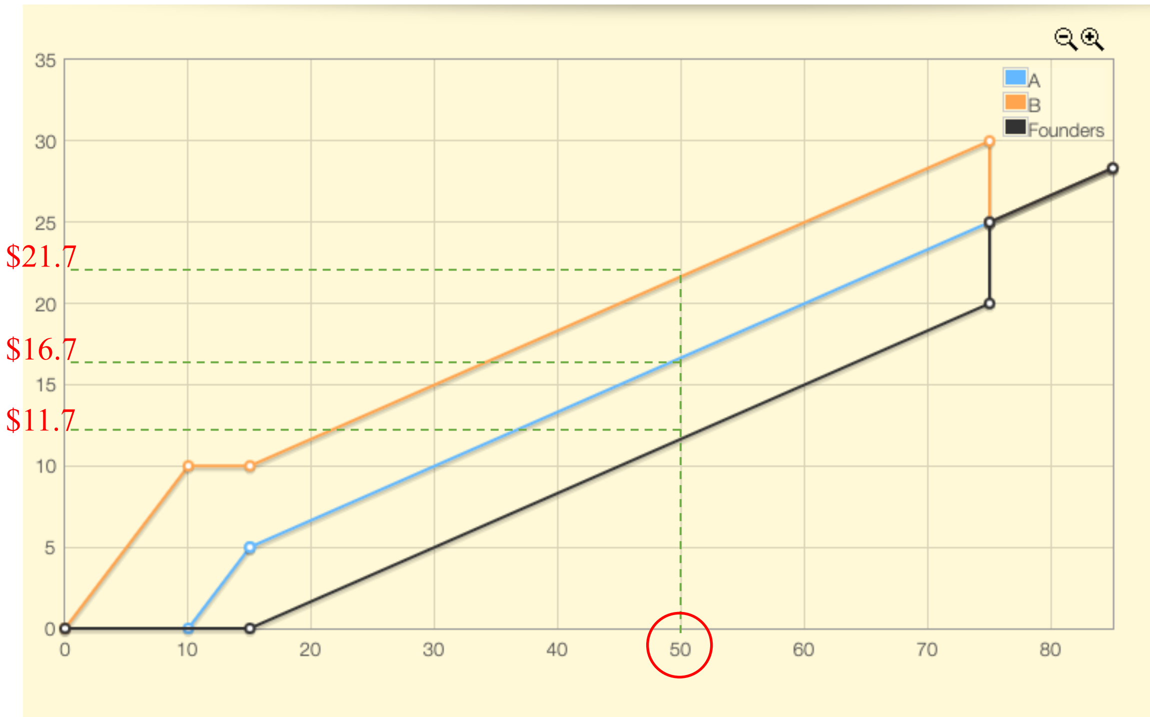


Figure 6: Multiple-round Example with Participation



Series B's purchase price = $2/share = fair value
Implied Series A's fair value = $1.16/share
Implied founders' common fair value = $0.78/share

Figure 7: Certificate of Incorporation Example

State of Delaware
Secretary of State
Division of Corporations
Delivered 06:14 PM 01/29/2014
FILED 06:09 PM 01/29/2014
SRV 140108856 - 4348296 FILE

RESTATED CERTIFICATE OF INCORPORATION
OF
DROPBOX, INC.

ARTICLE IV: AUTHORIZED SHARES

The Corporation is authorized to issue a total of 1,526,661,381 shares of its capital stock, which shall be divided into three (3) classes, designated "Class A Common Stock," "Class B Common Stock" and "Preferred Stock." The total number of shares of Class A Common Stock authorized to be issued is 700,000,000 shares, $0.00001 par value per share. The total number of shares of Class B Common Stock authorized to be issued is 600,000,000 shares, $0.00001 par value per share. The total number of shares of Preferred Stock authorized to be issued is 226,661,381 shares, $0.00001 par value per share, of which 95,810,910 are designated as "Series A Preferred Stock", 78,023,640 are designated as "Series A-1 Preferred Stock", 29,268,103 are designated as "Series B Preferred Stock" and 23,558,728 are designated as "Series C Preferred Stock."

1.9 ***"Original Issue Price"*** shall mean $0.06263 per share for the Series A Preferred Stock, $0.01605 per share for the Series A-1 Preferred Stock, $9.0491 per share for the Series B Preferred Stock and $19.1012 per share for the Series C Preferred Stock. The Original Issue Price shall be as adjusted for any additional stock splits or combinations of such Preferred Stock, stock dividends on such Preferred Stock, recapitalizations or reclassifications of such Preferred Stock or the like with respect to such Preferred Stock.

Figure 8. Sensitivity Analysis of Volatility, Holding Period, and Valuation Assumptions

On the y axis, we plot the ratio of the senior security value (i.e., the most recent deal price) to the modeled valuation of the average junior stake. Dots in the figure represent the mean ratio and whiskers depict the interquartile range at a given level of an input variable, which is varied along the x axis. Volatility, expected holding period, and enterprise value assumptions are varied in panels A, B, and C (respectively). Baseline assumptions are 90% annual volatility, a 3 year expected holding period, and an enterprise value implied by the senior security deal price.

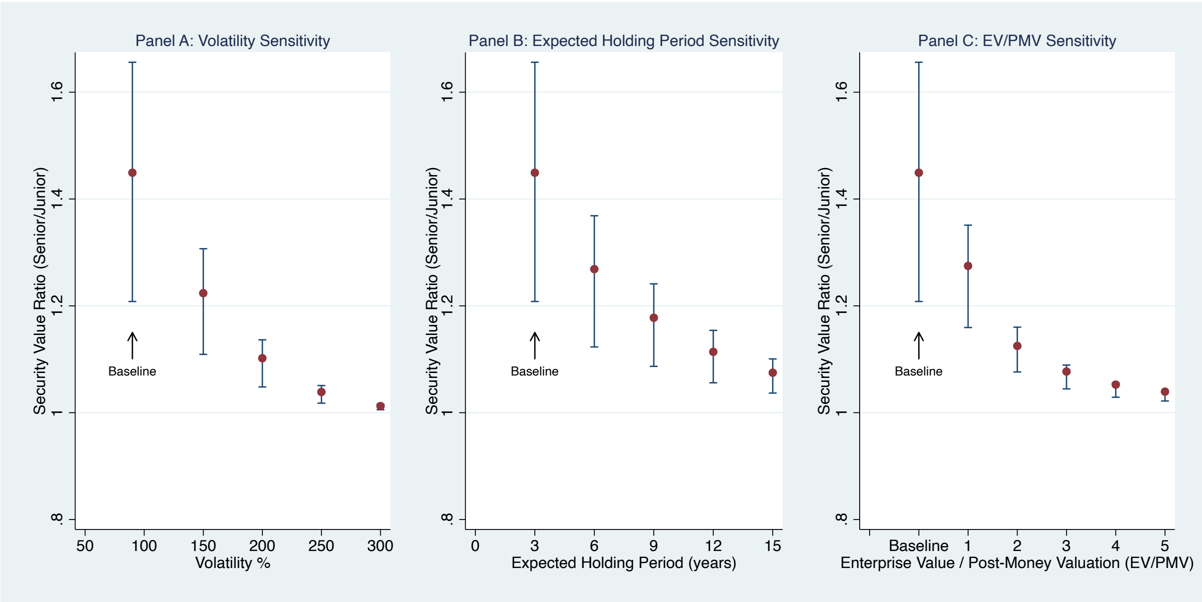


Figure 9: Box Plot of Absolute Deviation in Implied Enterprise Values

This figure plots the absolute deviation in implied enterprise values, which measures the magnitude of deviations in the enterprise value implied by the senior security value (*senior_EV*) and the enterprise value based on the junior security (*junior_EV*), $AbsDev\_EV = \left|\frac{senior\_EV}{junior\_EV} - 1\right|$. The box presents the interquartile range. The line within the box is the median. The top (bottom) whisker on the adjacent lines is the observation that is closest to the 75th (25th) percentile plus 1.5 times the interquartile range.

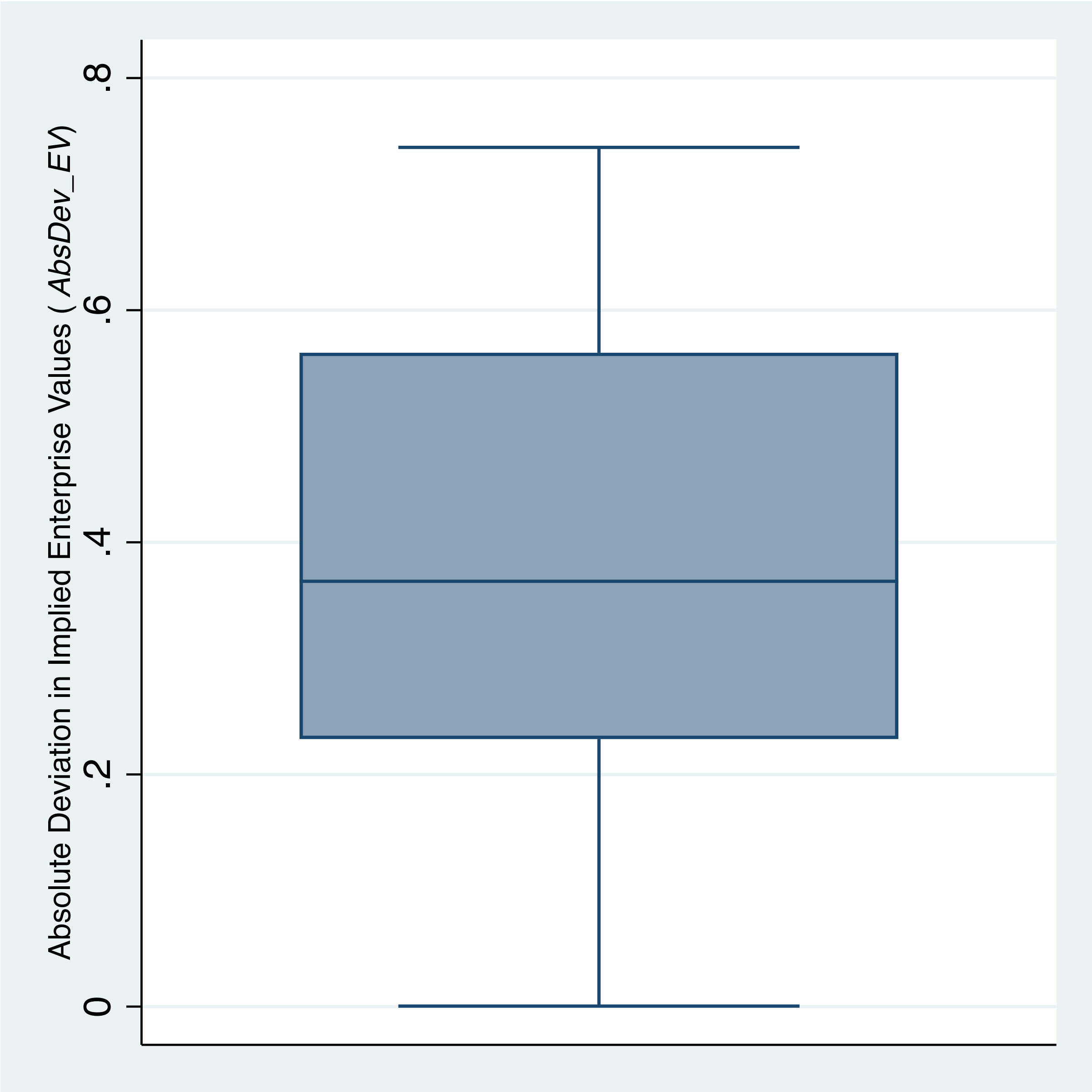


Figure 10: Exit Outcomes of Private Companies

The left graph plots the percentage of four possible outcomes over five years after the initial investment by mutual funds between 2010 and 2018: (1) exited through an IPO (IPO Exit), (2) exited through an acquisition (M&A Exit), (3) out of business before any exit (Bankrupt etc.), and (4) still a private company (Remain Private). The right graph plots similar exit outcomes for VC-backed private companies after the series C investment using data from 1987 to 2007 from Metrick and Yasuda (2021).

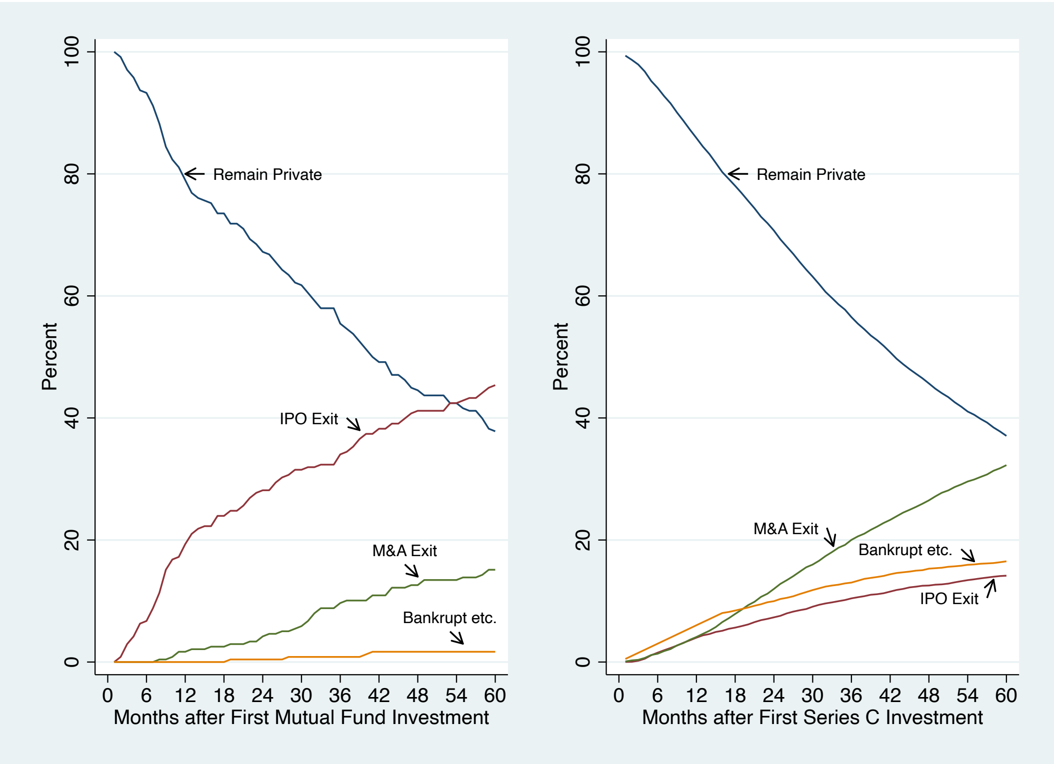


Figure 11: Examples of Secondary Purchases

This figure reports examples of secondary purchases of junior securities by mutual fund families in proximity of the latest senior security issue dates and in which the per share acquisition cost of junior securities is disclosed in their filings. “Series Acquired” refers to the junior securities purchased in secondary transactions. “Acquisition Cost” is the per share cost paid by mutual fund families to acquire the junior securities. “Latest Series” refers to the senior security issued and “Latest Issue Price” refers to the per share original purchase price of the latest senior security. “Acquired Series Fair Value” is the implied fair value per share of the junior security as of the latest series issuance date. “Excess Price Paid” referes to the implied overpayment per share by the mutual funds, calculated as (Acquisition Cost – Fair Value)/Fair Value.

Fund	Issuer	Series Acquired	Acquisition Cost	Latest Series	Latest Issue Price	Acquired Series Fair Value	Excess Price Paid
T ROWE PRICE GROWTH STOCK FUND, INC	TWITTER	Series A	16.13	Series G	16.09	8.62	87%
T ROWE PRICE GROWTH STOCK FUND, INC	TWITTER	Series B	16.09	Series G	16.09	8.62	87%
T ROWE PRICE GROWTH STOCK FUND, INC	TWITTER	Series C	16.13	Series G	16.09	8.62	87%
T ROWE PRICE GROWTH STOCK FUND, INC	TWITTER	Series D	16.09	Series G	16.09	8.63	86%
FIDELITY MAGELLAN FUND	DOCUSIGN	Series B	13.18	Series E	13.13	3.08	328%
FIDELITY MAGELLAN FUND	DOCUSIGN	Series B-1	13.34	Series E	13.13	3.08	333%
JOHN HANCOCK FUNDS II: MID CAP STOCK FUND	DOCUSIGN	Series B	13.13	Series E	13.13	3.08	327%
JOHN HANCOCK FUNDS II: MID CAP STOCK FUND	DOCUSIGN	Series B-1	13.13	Series E	13.13	3.08	326%
JOHN HANCOCK FUNDS II: MID CAP STOCK FUND	DOCUSIGN	Series D	13.13	Series E	13.13	5.69	131%
NEUBERGER BERMAN FOCUS FUND	SWEETGREEN	Series D	12.00	Series H	13.04	8.11	48%