Squaring Venture Capital Valuations with Reality*

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Abstract

We develop a financial model to estimate the fair value of venture capital-backed companies and of each type of security these companies issue. Our model uses the most recent financing round price and the terms of that financing to infer the value of each of their shares. Using data from legal filings, we show that the average highly-valued venture capital-backed company reports a valuation 51% above its fair value, with common shares overvalued by 62%. In our sample of unicorns – companies with reported valuation above $1 billion – almost one half (53 out of 116) lose their unicorn status when their valuation is recalculated and 13 companies are overvalued by more than 100%. Overvaluation arises because the reported valuations assume all of a company's shares have the same price as the most recently issued shares. In practice, these most recently issued shares almost always have better cash flow rights than the previously issued shares, so equating their prices significantly inflates valuations. Specifically, we find 53% of unicorns have given their most recent investors either a return guarantees in IPO (15%), the ability to block IPOs that do not return most of their investment (20%), seniority over all other investors (31%), or other important terms.

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1 Introduction

Venture capital (VC) is an important driver of economic growth and an increasingly important asset class. Of all the companies that went public in the U.S. since the late 1970s, 43% were backed by VC prior to their IPO (Gornall and Strebulaev (2015)). Historically, most successful VC-backed companies went public within three to eight years of their initial VC funding. More recently, many successful VC-backed companies have opted to remain private for substantial periods of time and have grown to enormous size without a public listing. Companies such as Uber, AirBnB, and Pinterest have been valued in the tens of billions of dollars – fueled by investor expectations that these companies will become the next Google or Facebook. The growth of these companies spawned the term "unicorn" that denotes a VC-backed company with a reported valuation above $1 billion. Once thought to be rare, as of early 2017, there are more than 200 unicorns around the world, with 113 unicorns based in the U.S.

With the reported valuation of these unicorns totaling over $600 billion, the interest in VC as an asset class has increased substantially. A number of the largest U.S. mutual fund providers, such as Fidelity and T. Rowe Price, have begun investing their assets directly in unicorns. In addition, third party equity marketplaces, such as EquityZen, allow individual investors to gain direct exposure to these unicorns. While the total present VC exposure of mutual funds, at around $7 billion, is small compared to the size of the mutual fund industry, there has been a ten fold increase in just three years. In 2015, Fidelity invested more than $1.3 billion into unicorns, more than any U.S. VC fund invested that year.[1]

Despite the growing importance and accessibility of VC investments, the valuation of these companies has remained a black box. This is partially due to the natural difficulty of valuing high-growth, illiquid companies. But to a large extent, this is due to the extreme complexity of VC-backed companies' financial structures. These financial structures and their valuation implications can be confusing and are grossly misunderstood not just by outsiders, but even by sophisticated insiders.

Unlike public companies, who generally have a single class of common equity, VC-backed companies typically create a new class of equity every 12 to 24 months when they raise money. The average unicorn in our sample has eight classes, with different classes owned by the founders, employees, VC funds, mutual funds, sovereign wealth funds, and strategic investors.

[1]Calculated from CRSP mutual fund data. Major investments include $235 million in WeWork, $183 million in Vice Holdings, $129 million in Zenefits, $118 million in Blue Apron, and $113m in Nutanix.

Deciphering the financial structure of these companies is difficult for two reasons. First, the shares they issue are profoundly different from the debt, common stock, and preferred equity securities that are commonly traded in financial markets. Instead, investors in these companies are given convertible preferred shares that have both downside protection (via seniority) and upside potential (via an option to convert into common shares). Second, shares issued to investors differ substantially not just between companies but between the different financing rounds of a single company, with different share classes generally having different cash flow and control rights.

Determining cash flow rights in downside scenarios is critical to much of corporate finance, and the different classes of shares issued by VC-backed companies generally have dramatically different payoffs in downside scenarios. Specifically, each class has a different guaranteed return, and those returns are ordered into a seniority ranking, with common shares (typically held by founders and employees, either as shares or stock options) being junior to preferred shares and with preferred shares that were issued early frequently junior to preferred shares issued more recently.

As a motivating example, consider the Square's October 2014 financing round where the company raised $150 million from a VC fund managed by GIC by issuing 9.7 million Series E Preferred Shares at a price of $15.46 per share. These convertible preferred shares entitle their holders to the greater of a fixed, preferred equity payout (called the liquidation preference) or to a variable, common equity payout (converted payout). The Series E Preferred Shares that Square issued promised to pay their holders $15.46 per share, ahead of all other shareholders, if Square was acquired. In an IPO, Series E Preferred Shares promised at least $18.56 per share, again ahead of other shareholders. If the per-share exit value exceeded those thresholds, Series E Preferred Shares could convert into common shares to gain that upside. These shares joined Square's existing Common and Series A, B-1, B-2, C, and D Preferred Shares. Each of these classes of shares has different cash flow, liquidation, control, and voting rights.

After this round, Square was assigned a so-called post-money valuation, the main valuation metric used in the VC industry. This post-money valuation is calculated by multiplying the per share price of the most recent round by the fully-dilluted number of common shares (with convertible preferred shares and both issued and unissued stock options counted based on the number of common shares they convert into). After its Series E round financing, Square had 256 million common shares and 132 million preferred shares, for a total of 388 million shares on a fully-diluted basis. Multiplying total shares by the Series E share price of \$15.46 yields a post-money valuation of \$6 billion:

$$\$6 \text{ billion} \quad = \quad \underbrace{\$15.46}_{\text{Series E Price}} \quad \times \quad \underbrace{388 \text{ million.}}_{\substack{\text{Total number of} \\ \text{shares in all classes}}} \tag{1}$$

Many finance professionals, both inside and outside of the VC industry, think of the post-money valuation as a fair valuation of the company. Both mutual funds and VC funds typically mark up the value of their investments to the price of the most recent funding round. Square's \$6 billion figure was dutifully reported as its fair valuation by the financial media, from *The Wall Street Journal* to *Fortune* to *Forbes* to *Bloomberg* to the *Economist*.[2]

The post-money valuation formula in Equation (1) works well for public companies with one class of share, as it yields the market capitalization of the company's equity. The mistake made by even very sophisticated observers is to assume that this same formula works for VC-backed companies and that a post-money valuation equals the company's equity value. It does not. Most public companies issue primarily fungible common shares, without distinct cash flow rights. VC-backed companies issue a variety of shares with different terms which means these shares have different values and we cannot use a formula like Equation (1), where all classes are assumed to have the same value.

For example, the IPO price of Square was \$9 per share, 42% below the price Series E investors had paid. However, Series E investors were contractually protected and received extra shares until they got \$18.56 worth of common shares. Series E shares must have been worth more than other shares, because they paid out more than other shares in downside scenarios and at least as much in upside scenarios. This difference in value is ignored in the post-money valuation formula. Equating post-money valuation with fair valuation overlooks the option-like nature of convertible preferred shares and overstates the value of common equity, previously issued preferred shares, and the total company.

[2]See, for example, http://www.wsj.com/articles/square-gets-150-million-lifeline-1412639052, http://www.forbes.com/sites/alexkonrad/2014/09/12/square-to-raise-100-million-at-a-6-billion-valuation/#7d8fdea6310f, http://fortune.com/2014/10/06/square-worth-6-billion-after-latest-150-million-fundraising-round/, https://www.bloomberg.com/news/articles/2014-08-28/square-said-in-talks-for-funding-at-6-billion-valuation, http://www.economist.com/news/finance-and-economics/21678809-profitless-payment-firm-goes-public-swiped. All accessed November 15, 2016.

In this paper, we develop a fully-fledged option-based financial model that derives fair valuation of each class of shares of VC-backed companies, taking into account the intricacies of contractual cash flow terms. We then use our model to value a large sample of U.S. unicorns.

Our model shows that Square's fair valuation after the October 2014 financing round was $2.2 billion, not $6 billion as implied by the post-money valuation. Square's reported post-money valuation overvalued the company by 171%. For a large sample of unicorns, we find overvaluation ranging from 5% to a staggering 205%. These unicorns' common shares and stock options are even more overvalued, because they are usually worth less than any convertible preferred share. Some unicorns have made such generous promises to their preferred shareholders that their common shares are nearly worthless.

Even sophisticated financial intermediaries equate the post-money valuation and fair value. For example, almost all mutual funds hold all of their stock of VC-backed companies at the same price. For example, after DraftKings' Series D-1 round, John Hancock reported holding DraftKings' Series D-1 and Common Shares at the same price.[3] We find the D-1 Preferred Shares were worth 43% more. Along the same lines, most mutual funds write up all of their share holdings of a given unicorn to the price of its most recent round of funding, regardless of the type of stock. For example, when Appdynamics issued a Series F round with an IPO ratchet, a provision offering a 20% bonus in down IPOs, Legg Mason wrote up their Series E Shares to the Series F price despite not being eligible for the 20% bonus. These examples are representative of common industry practices.

Conversations with several large LPs indicate that VC funds follow the same practice and mark their holdings up to the most recent round. Even within the VC industry, many people treat post-money valuations as the fair value of the company.

As another example, secondary equity sales site EquityZen describes the prices of common stock in terms of the price venture capitalists paid for preferred stock, without stating that the venture capitalists received a different security. For example, EquityZen markets a direct investment in the common shares of Wish, an e-commerce platform, as follows:

> EquityZen Growth Technology Fund LLC - Wish will purchase **Wish Common Stock**. The shares will be purchased at a cost of $49.00 per share, a **20.6% discount to the price**

[3] See, for example, https://www.sec.gov/Archives/edgar/data/1331971/000114544316001402/d299215.htm. Accessed January 27, 2017.

> **paid by recent investors on February 3, 2015**. On February 3, 2015, the company raised $514.0 million from Digital Sky Technologies and others, at an estimated $3.7 billion post-money valuation.
> *Retrieved from https://equityzen.com/invest/1037572/ on September 14, 2016. Emphasis in original.*

Although EquityZen provides nine pages of analysis on Wish, the fact that the valuation is set using preferred stock and that investors are buying common stock is not mentioned. The preferred stock that Digital Sky Technologies purchased here has strong preferences, including the right to its money back in exits other than IPO and a right to keep its preferred liquidation preference in an IPO, unless that IPO provides 150% returns. These can lead to stark differences in payout. If Wish is acquired for $750 million, all of the preferred equity investors get their money back while the common shares that EquityZen is selling get nothing.

The rank and file employees of VC-backed companies often receive much of their pay as stock options. The naïve approach, likely used by many of employees, would dramatically overvalue their wealth. For example, the stock options Square issued around the time of its 2014 funding round had a strike price of $9.11.[4] The naïve approach would take Square's 2014 financing round at $15.46 per share and view these options as $6 in the money. Our approach shows the "fair" common share price was actually closer to $5.62, so these options were significantly out of the money.

Even if a company's fair value is falling, it can report an increasing post-money valuation if it issues a new round with sufficiently generous terms. For example, Space Exploration Technologies, better known as SpaceX, issued Series D Preferred Shares in August 2008, during the early stages of the recent financial crisis. Despite the troubled economic times and several failed launch attempts, SpaceX managed to increase their post-money valuation by 36% from the previous round. Such a distortion became possible, because Series D Preferred Shares got highly attractive cash flow contractual terms. Namely, they were promised twice their money back and they were first in line in liquidations. Unsurprisingly, shares that promise investors twice their money back are more valuable than shares that promise investors nothing. According to our model, these generous terms mean that SpaceX's fair value was less than a quarter of its reported valuation. These generous terms are not necessarily evidence of active post-money

[4] See https://www.sec.gov/Archives/edgar/data/1512673/000119312515378578/d937622ds1a.htm. Accessed January 27, 2017.

valuation manipulation and could simply be due to a difficult fund raising environment. Irrespective of the company's intentions, the post-money valuation painted an overly rosy picture.

Our goal in developing the valuation model and applying it to a sample of unicorns is two fold. First, we hope to attract the attention of academic researchers to the increasingly important issue of the valuation of private companies. Our paper is inevitably just a first step in building a unified theoretical valuation framework. Our valuation estimates are substantially hampered by the lack of high-quality and consistent data on VC-backed companies and their financial structures. Both researchers and practitioners should devote more efforts to make such data available. Second, we hope to make different constituents of the VC industry – founders, employees, investors, regulators, and consultants – aware of the issues with interpreting the metrics traditionally used in the industry.

We develop the first academic contingent-claim valuation framework for valuing of VC-backed companies. Our paper is related to several important strands of the literature. Cochrane (2005), Harris, Jenkinson, and Kaplan (2014), Jenkinson, Harris, and Kaplan (2016), Kaplan and Schoar (2005), Korteweg and Sorensen (2010), and Korteweg and Nagel (2016) analyze the returns and the risk of venture capital as an asset class. Importantly, several of these papers take post-money valuations at face value and use them as a proxy for fair value, a practice we caution against. Chung, Sensoy, Stern, and Weisbach (2012), Litvak (2009), and Metrick and Yasuda (2010), and Robinson and Sensoy (2013) look at the role and impact of VC compensation provisions. Chakraborty and Ewens (2017) and Barber and Yasuda (2017) look at how venture capitalists report the value of their stakes to their investors. Bengtsson and Ravid (2015), Chernenko, Lerner, and Zeng (2017), Hellmann and Puri (2000, 2002) and Hochberg, Ljungqvist, and Lu (2007) look at the impact of different types of investors on portfolio companies and contracting. Cumming (2008) , Hsu (2004), and Kaplan and Strömberg (2003, 2004) explore VC contracting and the economics behind contractual terms.

Begining with Black and Scholes (1973) and Merton (1974), researchers have used share prices to value warrants, options, bonds, and other contracts. We reverse that process and use the price of option-rich preferred shares to value common shares. Our approach is close to the common practice of "option-adjusting" corporate bonds or mortgage-backed securities to back out underlying risk prices. Similar to our method, in this approach, risk-neutral valuation is used to account for the embedded call options in debt contracts to recover underlying default risk (e.g., Kupiec and Kah (1999); Stroebel and

Taylor (2009)). Although this approach is commonly employed in other areas of research, academics have not used it to value VC-backed companies.

The 409A tax valuations that VC-backed companies perform often use similar techniques. However, the primary goal of these valuations is to avoid fines in the event of a tax audit. The audit results are not used by decision makers – mutual funds and venture capital funds do not mark their shares to the 409A price. Because these valuations are not a strategic tool, accuracy is seen a lesser priority. Low values reduce taxes; coincidentally, 409A valuations commonly use questionable assumptions that significantly deflate values. For example, these valuations typically estimate volatility based on public comparables, yielding unrealistically low volatilities of 0.4-0.5 and correspondingly low estimates of the value of common stock.[5] 409A valuation provider eShare finds that common equity is overvalued by approximately 186% for the median Series C company – far above our median overvaluation of 38%.[6] Our assumptions, as discussed in Section 2.4, produce more conservative (and more realistic) estimates of overvaluation than the values used in 409A models. Our findings of significant overvaluation are not inconsistent with the views of VCs themselves. A survey of VCs by Gompers, Gornall, Kaplan, and Strebulaev (2017) shows that 91% of VCs think that unicorns are overvalued.

The rest of the paper proceeds as follows. In Section 2, we develop a model to value VC-backed securities. In Section 3, we provide a detailed description of the data sources and our methodology. In Section 4, we report the valuations of a sample of unicorns. In Section 5, we discuss these findings. Section 6 contains concluding remarks.

2 A Valuation Model of a VC-Backed Company

In this section, we develop a valuation model of a VC-backed company and apply it to contractual terms frequently used in the VC industry. We first build a contingent claims model in Section 2.1. We then detail how we apply this model to common contractual terms in Section 2.2. We finish this section by discussing our implementation in Section 2.3 and the parameters we use in Section 2.4.

[5]For example, Square used volatilities of 44–47% to value its stock options, as listed in its S-1 filing retrieved February 28, 2017 from http://www.nasdaq.com/markets/ipos/filing.ashx?filingid=10529767

[6]See page 8 in the eShares sample 409A model, retrieved March 28, 2017 from https://esharesinc.box.com/v/eshares-demo-model.

2.1 Contingent Claims Model

We use the price of a financing round to find the fair value of the VC-backed company at the time of the round. Consider a company that raises a VC round of amount I at time 0 using convertible preferred equity. This investment occurs at a post-money valuation of P, meaning that it entitles this round's VC investors to own I/P fraction of the company if the investors convert their preferred equity into common equity.

The company will exit at value $X(T)$ at some time T in an IPO, a sale, or a liquidation. We assume the investors are paid out at the time of exit.[7] The VCs' payoff is a function of the exit amount, $f(X(T))$. The form of the payout function f depends on the contractual features of securities used in that round, as well as all other rounds. As VCs rarely receive intermediate payoffs, it suffices to consider this terminal payout.

We use $V(t)$ to denote the discounted time-s value of the VCs' payoff and $X(t)$ to denote the discounted time-t value of the total exit. In order to discount these claims, we need to make assumptions about the company's exit value and exit time. As is common in contingent-claim models, we assume that $X(t)$ evolves according to a geometric Brownian motion with growth equal to the risk free rate r_f and volatility equal σ under the so-called pricing measure. This assumption is foundational to many areas of corporate finance and asset pricing. The time to exit is independent of $X(t)$ and exponentially distributed, $T \sim EXP(\lambda)$, where λ is the exit rate (and $1/\lambda$ is the average exit time). Metrick and Yasuda (2010) used the same set of assumptions to model VC investment cash flows. In Section 2.4 we show both sets of assumptions are reasonable for VC investments.

We assume that the VC round is fairly priced, so that the investment amount I equals the VCs' payoff discounted under the pricing measure:

$$I = V(0) = \mathbb{E}\left[e^{-Tr_f} f\left(X(T)\right)\right]. \tag{2}$$

[7] In reality, many investors receive payouts later than T because of various regulatory provisions, such as IPO lock ups, or negotiated agreements, such as incentives in mergers or acquisitions (M&A). For our purpose, we discount all of those payouts to time T.

Because $X(t)$ is a geometric Brownian motion, we can rewrite Equation (2) in terms of a standard normal random variable Z:

$$I = \mathbb{E}\left[e^{-Tr_f} f\left(X(0)\ e^{\sqrt{\sigma^2 T} Z + (r_f - \sigma^2/2)T}\right)\right]. \tag{3}$$

The company's time-0 value is simply the value of $X(0)$ that solves Equation (3) and fairly prices the VC round.

The most standard form of VC security is a convertible preferred equity, which gives the VCs the option to either a) convert into owning I/P fraction of the company or b) to liquidate and get a senior claim I, where I is their investment amount and P is the post-money valuation they invested at. The VCs' payoff is then the greater of their initial investment and I/P of the exit, limited to the value of the exit:

$$f(X(T)) = \min\left\{X(T), \max\left\{I, X(T) \times \frac{I}{P}\right\}\right\}, \tag{4}$$

In addition to this optional conversion, most VC contracts contain automatic conversion (also known as mandatory conversion) clauses that force conversion when a trigger event occurs. The trigger event is commonly an IPO that raises a sufficiently large amount of money, referred to as a qualified IPO. In such a qualified IPO, preferred shares must convert into common shares even if that conversion reduces their payout (e.g., the IPO price is below their liquidation preference).

We model automatic conversion terms by writing the exit payoff, $f(X(T))$, as the sum of the payoff in an IPO, $f^{IPO}(X(T))$, and the payoff in an M&A exit, $f^{M\&A}(X(T))$, weighted by the probability of each outcome conditional on the exit value, $p^{IPO}(X(T))$ and $1 - p^{IPO}(X(T))$:

$$f(X(T)) = p^{IPO}(X(T))\, f^{IPO}(X(T)) + \left(1 - p^{IPO}(X(T))\right) f^{M\&A}(X(T)). \tag{5}$$

If an automatic conversion is triggered, the VCs get their converted payoff:

$$f^{IPO}(X(T)) = X(T) \times \frac{I}{P}. \tag{6}$$

Otherwise, the VCs have the same choice between conversion and liquidation that they have in M&A exits:

$$f^{IPO}(X(T)) = f^{M\&A}(X(T)). \tag{7}$$

According to industry practitioners, it might be difficult for the company to go public unless all of the preferred shares convert. We therefore assume that if any VCs are not automatically converted and they prefer an M&A exit, they will force an M&A exit.

We have considered a single financing round; however, the calculations follow identically as long as future financing rounds do not make current investors better off or worse off. Equivalently, we need that future financings occur at a fair price and do not redistribute wealth between the existing investors. Section 4.3.1 relaxes this assumption. In the following sections, we add subscripts to denote round n (I_n, P_n, f_n) which happens at time t_n.

2.2 Modeling Contract Terms

In this section, we introduce the key cash flow terms used in VC financings and how these terms impact valuation. In practice, each issued security is the outcome of negotiation between existing investors, new investors, and company management, and so each contract has a unique set of terms (see, e.g., Kaplan and Strömberg (2003)). Our model can be used to price all of these modifications by adjusting the payoff function f. In this section, we identify and discuss the most important contractual terms and institutional details. The results in Section 4 are based on the unique contractual terms of each company in our sample, including both these terms and terms such as cumulative dividends, anti-dilution triggered in IPOs, and time varying terms that we omit below for brevity.

Baseline case. To illustrate the impact of the terms discussed below on valuation, consider a prototypical unicorn that is raising $100 million of new VC investment with a post-money valuation of $1 billion using standard preferred shares with a conversion option, automatic conversion in IPOs, a return of initial investment in M&A exits and liquidation events, and no additional provisions. In the past, this company raised $50 million of VC investment at a post-money valuation of $450 million using the same type of standard preferred shares and these shares have the same seniority as the most recently issued shares. In our model, $P_1 = 450$, $P_2 = 1,000$, $I_1 = 50$, and $I_2 = 100$ (all values in millions). After the current round, the new investor owns 10% of the total shares, the old investor owns 10%, and common stock constitutes the remaining 80%.

Putting this together, the payout to the new investor in the case of an IPO is the converted payoff in Equation (6) and the payout in an M&A exit is as follows:[8]

$$f_2^{M\&A}(X) = \max\left\{\min\left\{\frac{I_2}{I_1+I_2}X, I_2\right\}, X \times \frac{I_2}{P_2}\right\}. \tag{8}$$

Table 1 shows the fair valuation of the company and its common stock as implied by the model. All the parameters used in the model calibration are discussed in Section 2.4. We define company's overvaluation, Δ_V, as the ratio of post-money valuation to fair value implied by the model and similarly define the common shares' overvaluation, Δ_C, as the ratio of the post-money share price to the fair value of a common share. The first row shows that if the most recent round is fairly priced at a post-money valuation of \$1 billion, the company has fair value of \$771 million. The post-money valuation exaggerates the company's value by 30% and the value of common shares by 28%.

We now introduce a number of the important contractual modifications used by unicorns that impact valuation. In the model, the variation of these contractual provisions affects valuation by changing f_2 and f_1. The Online Appendix contains examples of each of these.[9]

Liquidation preference. Liquidation preference terms give investors a higher guaranteed payout in non-IPO exits. The baseline case considers preferred shares that entitle investors to a minimum of their money back, referred to as 1X. Most unicorns have liquidation preferences of 1X, but other preferences are commonly used. For example, Uber's Series C-2 Preferred Shares had a 1.25X liquidation preference, promising these investors 1.25 times their money back, and AppNexus's Series D Preferred Shares had a liquidation preference of 2X, promising these investors twice their money back. If the new VC investor is guaranteed L times their money back in an M&A exit, rather than 1 times their money back, Equation (8) becomes

$$f_2^{M\&A}(X) = \max\left\{\min\left\{\frac{L \times I_2}{I_1+L \times I_2}X, L \times I_2\right\}, X \times \frac{I_2}{P_2}\right\}. \tag{9}$$

[8] Equation (8) differs from Equation (4) because there are now two classes of investors.

[9] The Online Appendix to this paper can be found at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2968003.

Such a guarantee increases the value of preferred shares and increases overvaluation. As Table 1 shows, a 1.25X liquidation preference increases overvaluation from 30% to 42%, while giving her a 2X liquidation preference increases overvaluation to 94%.

Option pool. Almost all the VC financing rounds include an option pool, which is a set of unissued shares that are held aside for future option-based employee compensation. The post-money valuation approach includes these unissued options in the valuation, which is theoretically incorrect. Plans for future dilutive share issuances do not increase the current fair value of a company: a company cannot arbitrarily increase its value by authorizing (and not issuing) a large number of shares. Beyond governance issues, the timing of the authorization does not impact cash flows, and only the timing of actual issuance matters. Rather than authorizing the options at the time of the round, the company could authorize options immediately after the round with no change in real cash flows.

In our baseline case, we assume that unissued stock options are 5% of the total post-money valuation. Table 1 shows how results change for the cases of 0% and 10% option pools. Assuming there are no unissued shares included in the post-money valuation decreases overvaluation at the company level from 30% to 23%, but has only a small effect on the overvaluation of common stock. Assuming that unissued options make up 10% of the company's shares increases overvaluation to 37%. Option pools mean that for companies where preferred shares have few additional rights, common stock may be less overvalued than the total post-money valuation.

Seniority. Many unicorns make their most recent investors senior, so that their liquidation preference must be satisfied before other investors receive anything. For example, Interacia Therapeutics Series EE Preferred Shares and Magic Leap Series C Preferred Shares were both made senior to all the previous preferred equity investors when they were first issued. Making an investor class senior increases their payouts in low M&A exits:

$$f_2^{M\&A}(X) = \max\left\{\min\left\{X, I_2\right\}, X \times \frac{I_2}{P_2}\right\}. \tag{10}$$

As Table 1 shows, making the new investor senior increases company overvaluation to 36% and common share overvaluation to 35%. In theory, the new investor could also be junior to existing investor:

$$f_2^{M\&A}(X) = \max\left\{\min\left\{X - I_1, I_2\right\}, X \times \frac{I_2}{P_2}\right\}. \tag{11}$$

We do not observe the junior status of new investors in practice, but even in this case there is still significant overvaluation because even junior preferred equity is senior to common equity.

Participation. Participation gives VCs that do not convert a payout equal to the sum of both their liquidation preference *and* their converted payout. This liquidated payoff is typically limited to some cap, C, and in order to get a payoff in excess of C, the VCs must convert. Several unicorns use this term, such as Proteus Biomedical where all Preferred Shares enjoy uncapped participation or Sprinklr where the Series B Preferred Stock participates with a 3X cap and the Series C Preferred Stock participates with a 2X cap. Even in our simple illustrative case, the payout formula is complicated, as caps result in a multi-kinked payoff function:

$$f_2^{M\&A}(X) = \begin{cases} \frac{I_2}{I_1+I_2}X & \text{if } X \leq I_1 + I_2 \\ \max\left\{\min\left\{CI_2, I_2 + (X - I_2 - I_1) \times \frac{I_2}{P_2}\right\}, \frac{I_2}{P_2}X\right\} & \text{if } I_1 + I_2 \leq X \leq P_1 + I_2 \\ \max\left\{\min\left\{CI_2, I_2 + (X - I_2) \times \frac{I_2}{P_2}\right\}, \frac{I_2}{P_2}X\right\} & \text{if } P_1 + I_2 \leq X \end{cases}. \tag{12}$$

Participation increases the value of preferred stock relative to common, which increases overvaluation. As Table 1 shows, giving the new investor participation without a cap leads to a dramatic increase in overvaluation, from 30% to 53%. Caps reduce that overvaluation only slightly: 52% overvaluation persists even with the empirically common 2.5X cap.

IPO Ratchet. IPO ratchet terms give some investors extra shares in IPOs with share prices below a pre-agreed threshold. Pivotal, Oscar, and many other unicorns gave their most recent investors an IPO ratchet that ensures those investors always at least break even in IPOs. Some contracts go further: Series E Preferred Shares in Square were guaranteed at least a 25% return and Series D Preferred Shares in Compass were promised a 32.5% IRR. If the new investor is entitled to R times the initial investment in an IPO, her IPO payout becomes

$$f_2^{IPO}(X) = \max\left\{\min\left\{X, R \times I_2\right\}, X \times \frac{I_2}{P_2}\right\}. \quad (13)$$

Predictably, these terms have a large impact on valuation. Guaranteeing the new investor her money back in any IPO increases overvaluation to 56%; guaranteeing her a 25% return increases overvaluation to 75%.

Automatic Conversion Exemption. Automatic conversion provisions force preferred equityholders to convert their shares in an IPO, even if it is against their best interests. The most recent investors stand to lose the most in automatic conversions as they usually have the highest liquidation preferences. Thus, the negotiated investment contracts frequently allow automatic conversions only in IPOs with sufficiently high per share values, total proceeds, or total values. For example, Evernote exempted all preferred shares from automatic conversion for IPOs below $18.04 per share when it raised its Series 6 round, Kabam exempted all preferred shares for IPOs with proceeds below $150 million when it raised its Series E round, and SpaceX exempted all preferred shares for IPOs with value less than $6 billion when it raised its Series G round. Some contracts provide different automatic conversion exemptions to different classes of share. The Honest Co gave Series A and A-1 Preferred Stock an exemption for IPOs priced below $18.1755 per share or with proceeds below $50 million, Series B Preferred Stock an exemption for IPOs with proceeds below $50 million, Series C Preferred Stock an exemption for IPOs with proceeds below $75 million, and Series D Preferred Stock an exemption for IPOs with proceeds below $100 million.

In many cases, there are additional terms that can allow a majority of preferred shares voting together to force the conversion of preferred shares, even when there is not a qualified IPO. Early preferred investors will often have an incentive to force the conversion of the latest investors, due to dramatic differences in liquidation preferences. We assume that preferred classes vote strategically and so we do not count automatic conversion exemption if they will be overridden by such a vote.

If the new investors are granted an automatic conversion exemption, their payoff in an IPO becomes

$$f_2^{IPO}(X) = \begin{cases} f_2^{M\&A}(X) & \text{if } f_2^{M\&A}(X) > X \times \frac{I_2}{P_2} \\ X \times \frac{I_2}{P_2} & \text{otherwise} \end{cases} . \tag{14}$$

Table 1 shows that automatic conversion exemptions results in overvaluation of 55% if the new investor can avoid converting unless they receive 1X returns. Even exemptions that only bind on low IPOs, such as 0.75X or 0.5X exemptions, lead to 48–54% overvaluation. As VC-backed companies are highly volatile, a value loss of more than 50% is not unlikely and the ability to force a liquidation in low-IPOs is valuable.

Investment Amounts. The size of the investment also impacts the overvaluation. For example, if the new VC invests $900 million at a $1 billion valuation, the company's fair value after the investment must be at least $900 million, which does not leave much room for overvaluation. Table 1 shows overvaluation for more empirically relevant investment amounts. A substantial investment of $I_2 = \$400$ million leads to an overvaluation of 14%. At the other extreme, if the VC only invested $10 million, the overvaluation rises to 44%.

The size of the previous round also matters. Because the new shares are senior to common equity and pari-passu with the previously issued preferred shares, if there are more existing preferred shares and less common, the new shares are less senior and overvaluation falls, as illustrated in Table 1.

Application to Square. To provide an illustration of how the model prices of an actual unicorn, consider the case of Square. Before its IPO, Square issued $551 million in equity across six rounds, most recently with the issuance of a $150 million Series E round in October 2014 and a $30 million Series E follow up in October 2015. Table 2 reports the information on all of the equity funding rounds of Square, using the methodology discussed in Section 3.3.

In a liquidation or sale, Square's Series E Shares were guaranteed a payout of $15.46 and that claim was senior to other claims. In an IPO, Square's Series E Preferred Shares had a 1.2X ratchet, with extra shares delivered if the IPO price failed to deliver a 20% return to Series E investors. Clearly, these special protections make Series E Shares more valuable than the common shares that lack any such protections. However, the post-money valuation formula assumes each class of share has the same value. As reported in *The Wall Street Journal*, Square's post-money valuation after its October 2014 round was \$6 billion:

$$\$6 \text{ billion} = \underbrace{\$15.46}_{\substack{\text{Series E} \\ \text{Issue Price}}} \times \Big(\underbrace{233 \text{ million}}_{\substack{\text{Common Shares} \\ \text{and Options}}} + \underbrace{19 \text{ million}}_{\substack{\text{Unissued} \\ \text{Options}}} + \underbrace{47 \text{ million}}_{\substack{\text{Series A} \\ \text{Preferred Shares}}} + \underbrace{14 \text{ million}}_{\substack{\text{Series B-1} \\ \text{Preferred Shares}}} + \cdots + \underbrace{10 \text{ million}}_{\substack{\text{Series E} \\ \text{Preferred Shares}}} \Big). \tag{15}$$

Table 3 uses our model to price each of Square's shares at the time of its October 2014 round. A fair value of \$2.2 billion correctly prices Square's \$6 billion Series E round. Based on that fair value, we can price each of the other share classes.

We see that Square's Series E shares are worth three times the price of its Common shares and its Series A and B Preferred shares. Square's unissued stock options are worth nothing because they are not part of the company's value. Because most of Square's shares are worth less than half of the Series E price, Square's post-money valuation overstated its fair value by 171%.

In November 2015, Square went public at \$9 per share and pre-IPO value of \$2.66 billion. The Series E preferred investors were given \$93 million worth of extra shares because of their IPO ratchet clause. The IPO was at substantially less than the post-money valuation of October 2014 – our model suggests these down exits are likely for a number of highly overvalued companies. Our model is designed to produce fair value estimates that are better proxies for expected value at exit than post-money valuations are.

2.3 Model Implementation

Beyond the simplest contracts, our model does not have a closed-form solution, especially in light of the complicated capital structures of unicorns. We therefore value securities by simulating numerous exits and evaluating the exact contractual payoffs of each class of shares at that exit. We first simulate a large number of potential exits for the company by generating random exit times T and random values at exit X, according to distributions discussed in Section 2.4.

For each exit, we then calculate the payoff to each class of securities. This is not always straightforward, because these companies typically have many classes of securities. We start by determining which securities can choose not to convert. If the exit is an M&A, every preferred shareholder has this choice. If the exit value is a qualified IPO, then securities must convert unless their class has an automatic conversion veto.

As the first step in the payoff calculation, we assume that all classes of shares convert. In this case, payoffs are the exit value multiplied by the number of shares each class converts into divided by the total number of converted shares. Then we iterate through each class of shares that can choose whether or not to convert, checking whether they would optimally choose not to convert. If they choose not to convert, we recalculate all of the payoffs and restart this step. For all of the companies we consider, this converges to a Nash equilibrium.

Each class of shareholders acts strategically and excises its conversion option, votes, and uses vetos to maximize its payoff. For example, if Series A Preferred Shares take part in a vote to force the automatic conversion of all classes of preferred shares, we assume Series A Preferred Shares will vote in a way that maximizes the payout to Series A Preferred Shares. This assumption may not be correct to the extent that different investors may have dominant positions in more than one class of shares. While we have quite good data on the identity of investors for most unicorns, we cannot verify how much they actually invested in each round, because most rounds feature more than one investor.

Given the equilibrium conversion choice, we calculate the contractually specified payouts. This usually means iterating in order of seniority, paying off each class completely in a prorata fashion if any member of that class chose not to convert. After liquidation payouts, the surplus cash is distributed prorata to common equity, converted preferred shares, and participating shares. We limit the payoff of participating shares to their cap, and distribute the resulting surplus across common equity and any participating shares that have not hit their cap. Shares with cumulative dividends have those dividends added to their final payout.

2.4 Parameters

In this section, we discuss the calibration of our key model parameters: volatility σ, exit rate λ, IPO probability p^{IPO}, and risk free rate r_f. Some parameters are difficult to estimate, necessitating ad hoc assumptions. We strive to be conservative and use parameters that do not inflate overvaluation. Charts in the Online Appendix illustrate how variation in these parameters impacts overvaluation and further robustness checks are contained in Section 4.3.

Volatility σ. We use 0.9 as our baseline volatility parameter. Cochrane (2005) estimates the annualized volatility of VC investment returns at 0.89. This estimate is used by Metrick and Yasuda (2010) and others. Ewens (2009) and Korteweg and Sorensen (2010) use fuller selection models and get volatility estimates between 0.88 and 1.3.[10]

An argument could be made for somewhat lower volatility to account for the late stage and developed status of unicorns. It is likely that these large companies have lower volatility than early stage VC-backed companies, similar to the lower return volatility exhibited by highly-valued public companies relative to the universe of all public companies. For example, over the 2011–2016 period, NASDAQ companies with valuations above $1 billion had a volatility of 0.32, about 28% less than the NASDAQ average of 0.45. The literature, however, is inconclusive on the relationship between stage and volatility for VC-backed companies.

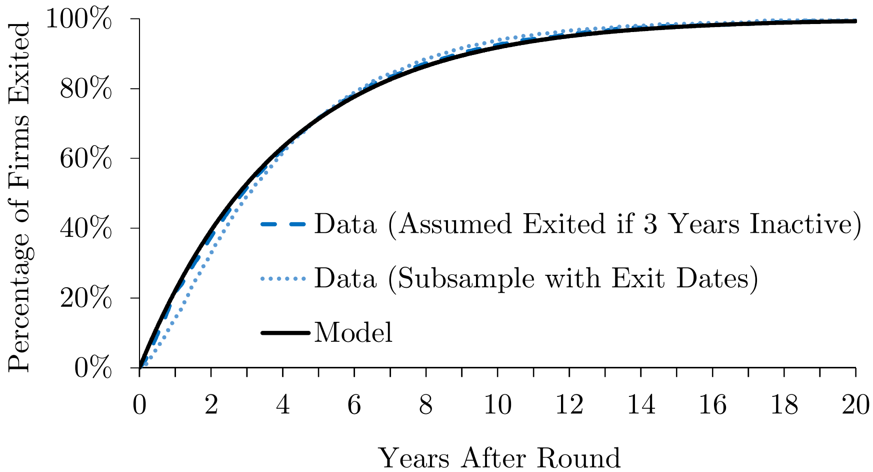
The relationship between overvaluation and volatility is non-monotonic. We perform extensive robustness checks for the ranges of volatility between 0.5 and 1.3 and find that overall the results are relatively insensitive to changes in volatility, with overvaluation varying between 26% and 31% in this range.

A potential concern is that VC returns are substantially skewed and non-normal. This does not appear to be the case empirically as Korteweg and Sorensen (2010) find only slight deviations from normality and the Online Appendix provides further justification that lognormality is a reasonable assumption.

[10]All of these researchers take valuations as fair values when calculating volatility. It is unclear how overvaluation would impact volatility estimates in a fully formed selection model.

Figure 1: Time to Exit Dispersion in VentureSource and Model Generated Data

In Figure 1, we plot the probability that firms have exited at different times after their financing round. Our model (solid line) has firms exit at an exponential rate of $\lambda = 0.25$. This is compare to time to exit for forth or later VC rounds in VentureSource data from mid-1992 to mid-2015. We look at both firms with reported exits (dotted line) and firms that either reported an exit or were inactive for three years (dashed line). We assume the inactive firms failed uniformly in the year after their last reported financing round.



Exit Rate λ. To estimate the rate, λ, at which unicorns exit, we use data on the exits from Dow Jones VentureSource. While VentureSource has relatively complete data on the dates of funding rounds, IPOs, mergers, and acquisitions, the dates of failures are generally not reported and companies remain "active" long after their demise.

We look at exits for companies that exited between July 1, 1992 and July, 1 2015 using VentureSource data. As we are interested in unicorns, we restrict our focus to companies with at least four rounds of VC financing. We have data on 10,523 such companies and we have reported exits for 4,649 of them. For the companies that report an exit, the average time between the fourth round and an exit is 3.9 years, while between the time between sixth round and an exit there is 3.5 years. As the baseline parameter, we take the value of 0.25 for λ, which results in an average expected exit time of 4 years. Metrick and Yasuda (2010) use a similar exponential distribution assumption, but with a rate of 0.2 for their sample including early-stage VC-backed companies. As unicorns are larger, more mature, and closer to exit, we use a higher rate of 0.25 to better match the data.

In Figure 1, we plot the probability that a company has exited as a function of time since financing. As the figure shows, the model distribution is relatively close to the empirical distribution of exit times for those companies with exits.

Figure 1 also plots the empirical distribution of all companies (including those without reported exits) by assuming that companies with no activity for three years have failed. We assume those failures occurred at a uniform rate between zero and one year after their final financing. As we do not have three full years post-financing for companies that received financing in 2013, we censor our exits in mid-2012. Again, the survival function is close to our exponential assumption.

M&A and IPO Exits. The probability of an IPO exit and the corresponding probability of an M&A exit is an important input in our model as IPOs can lead to automatic conversion. In Figure 2, we look at IPO and M&A exits reported in VentureSource for the 2007–2016 period.[11] We also examine the ratio of M&A to IPO exits at each level of valuation (to make IPOs comparable to M&A exits, we set IPO values equal to the post-money valuation of the IPO minus the IPO proceeds).

The results in Figure 2 suggest that the popular belief that firms with exit values above \$1 billion inevitably choose IPO is not correct. M&A exits are frequent even among the largest exits – in fact, the two largest exits of the past three years are WhatsApp's \$22 billion sale and Stemcentrx's \$10.2 billion sale. Based on that data, we calibrate the following piecewise linear function for the probability of an IPO exit for a given exit value:

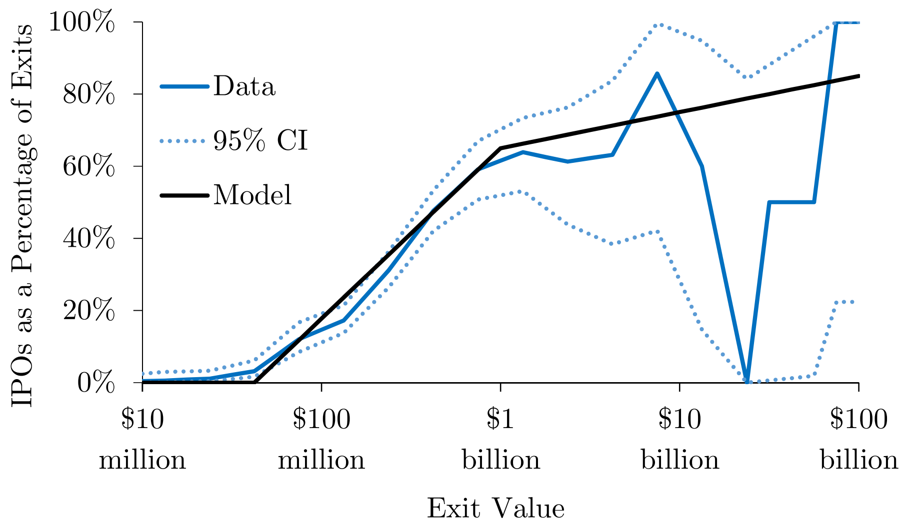
$$p^{IPO}(X) = \begin{cases} 0 & \text{for } X \leq \$32m \\ 0.65 \times \frac{\log(X) - \log(\$32m)}{\log(\$1b) - \log(\$32m)} & \text{for } \$32m \leq X \leq \$1b \\ 0.65 + 0.2 \times \frac{\log(X) - \log(\$1b)}{\log(\$100b) - \log(\$1b)} & \text{for } \$1b \leq X \leq \$100b \\ 1 & \text{for } \$100b \leq X \end{cases} \tag{16}$$

Note that these estimates allow for very large M&A exits. However, very large M&A deals are far from unknown in the technology space. For example Vodafone's \$172 billion purchase of Mannesmann

[11] We use a shorter sample here than for the exit type calculations to better track the recent rise in large M&A exits. While we use a long sample for the exit rate data in order to plot exit rates 20 years out, exit rates in the more recent sample are not significantly different.

Figure 2: Probability of an IPO Conditional on Exit in VentureSource and Model Generated Data

Figure 2 plots the probability of an IPO exit conditional on exit value. Our model (solid line) is compared to Dow Jones VentureSource data from 2005 to mid-2015 on the exits of VC-backed companies. We group companies into companies into buckets with log-10-width of 0.25, for example \$10–17 million and \$17–31 million, and plot the resulting probability estimates (dashed line) and their 95% confidence interval (dotted lines).



in 1999, AOL's \$165 billion purchase of Time Warner in 2000, or Pfizer's \$160 billion merger with Allergan in 2015. Also note that the treatment of the largest exits is not material for our calculations, as all investors choose to convert and take the IPO payout in these cases.

A more minor input to our model is the level of IPO proceeds. This matters for automatic conversion exemptions that are stated in terms of IPO proceeds. We assume that IPO proceeds are 25% of the value of the company pre-IPO, matching the median in our VentureSource sample. We perform robustness checks with a range of IPO proceeds values.

Risk-free Rate r_f. We use the value of 0.025 for the risk free rate. In the era of very low interest rates, this is likely on the higher end of the reasonable range. Note, however, that overvaluation monotonically decreases as risk-free rate rises, and therefore our choice of 0.025 is relatively conservative.

3 Data

This section details how we build a sample of U.S. unicorns and gather their financial structure data. We first discuss commercial data sets and legal filings used in our analysis (Section 3.1). Then, we describe how we construct our sample of unicorns (Section 3.2). Finally, we discuss how we derive the capital structure inputs our model needs from legal filings and commercial data sets (Section 3.3).

3.1 VC Data Sets and Legal Filings

Our main source of financial structure information is corporate legal filings. A Certificate of Incorporation (COI) is a legal document that forms a company's charter and lays down the contractual relationships between various classes of shares. COIs include information on contractual terms, such as the original issue price and various investor protections, for each class of preferred shareholders. We get these COIs from a company called VCExperts, which has a substantial number of scanned COIs from Delaware and other states.

A company must file a re-stated COI each time it changes any of the terms of its COI, such as when it authorizes new securities for an equity financing round. Because of this, we have multiple COIs for most unicorns in our sample, allowing us to trace out the path of their fund raising. For example, we have 20 COIs for Uber.

COIs are complicated and often convoluted legal documents. There is no accepted terminology for many terms (e.g., forced conversion is called either automatic or mandatory in different COIs) and there is a large variety of ways a COI can be structured and written. We employed a team of three attorneys and one law school student to extract and code this data. All COIs were analysed by one lawyer (in most cases two) and one (in some cases both) of the coauthors. Chernenko, Lerner, and Zeng (2017) use this data source to look the control rights and cash flow rights given to mutual fund investors in unicorns.

We supplement this information with basic data from commercial VC data sets, such as amount raised in each round, post-money valuation, and company founding date. Our primary source for this data is Dow Jones VentureSource. We supplement and cross-check VentureSource with Crunchbase, Thomson

One, CB Insights, and PitchBook. We utilize multiple data sources because they gather data in different ways and as a result they are often inconsistent with each other. Funding rounds are frequently not reported, incompletely reported, or misreported in each data set and using multiple data sets allow us to minimize the impact of data errors and fuzziness.[12] In a number of cases, we consulted newspaper reports and the COIs themselves to arrive at consistent information and to reconcile differences between our data sources.

Note that several of these commercial data sets contain information on contract terms. Unfortunately, these data sets miss automatic conversion vetos and ratchets, two of the most important terms for valuation, and have mixed quality on other terms. Because of this, we hand collect data for our sample from COIs.

3.2 Sample of Unicorns

We define a unicorn as a VC-backed company with a post-money valuation over $1 billion in at least one of its private rounds of financing. This definition includes companies that were valued over $1 billion in the past and whose valuation subsequently decreased. This definition excludes companies whose only valuation over $1 billion was the value at exit (either the IPO valuation or the M&A value). To focus on fast growing companies, we restrict our sample to companies that were founded after 1994 and have had a venture capital round after 2004. We further limit our sample to U.S. companies as we are unable to gather contract data for foreign companies.

With these restrictions in mind, we compile a list of potential unicorns by combining the unicorn lists created by CB Insights and Fortune with an export of the companies having highly valued rounds in VentureSource or Thomson One.[13] This analysis generated 184 companies. For each of those companies, we gathered its financing history across databases and confirmed that it was indeed VC-backed and that

[12] For example, consider LetterOne Group's widely-reported $200 million investment in Uber in January 2016. Crunchbase and CBI report this round without a valuation, VentureSource reports it with an estimated valuation of $14 billion, Thomson One reports that it with a valuation of $7 billion, VC Experts reports that the round was part of a larger round with an unknown valuation, and Pitchbook reports it as part of a $5.6 billion round at a $66.6 billion post-money valuation. All values accessed on February 21, 2017.

[13] For CB Insights, the unicorn list is available at https://www.cbinsights.com/research-unicorn-companies. We retrieved CB Insights data twice, resulting in two lists on April 16, 2016 and November 16, 2016. For Fortune, the unicorn list is available at http://fortune.com/unicorns/, retrieved April 16, 2016.

it had a post-money valuation over $1 billion. 38 companies did not satisfy at least one of these criteria. This resulted in the unicorn sample of 146 unicorns. The full list is given in the Online Appendix.

Table 4 provides summary statistics of our unicorn list. Out of 146 unicorns, 107 are still private as of February 2017, 26 went public, 11 were acquired, and 2 failed (Solyndra and Better Place). We exclude 12 companies where we are unable to find the COI for their latest venture capital round, bringing our sample to 144. We also exclude 18 companies where we have the latest COI, but we are missing key information. For example, Stripe defines the Series B original issue price (OIP) as follows in its November 2016 COI: *"the original price per share paid to the Corporation by check, wire transfer, cancellation of indebtedness or any combination of the foregoing for the Series 8 Preferred Stock in accordance with a written agreement with the Corporation setting forth the purchase price per share of such Series B Preferred Stock"*. This definition does not provide the value of OIP, which does not allow us to calculate other quantities. Another example is Mozido's December 2014 COI which references a Put Agreement that was not filed with Delaware and thus not visible.

Our final sample, on which all of the subsequent analysis is based, consists of 116 unicorns. Comparison between the final sample and the total sample of 146 unicorns suggests that these samples are similar along many dimensions. In both samples, the average unicorn was founded in 2007 in California, raised 7 rounds of funding, and most recently raised a round of about $200 million at a valuation of about $3 billion post-money valuation in 2015.

3.3 Financial Structure and Cash Flow Terms

COIs list plethora of company-specific information. In particular, they list the main contractual relationships between classes of shareholders that could be important in a court of law. For example, each COI reports the number of shares it is authorized to issue in each class. Square's October 2014 COI authorizes 6 classes of preferred share:

> The total number of shares which the Corporation is authorized to issue is 580,339,499 shares, each with a par value of $0.0000001 per share. 445,000,000 shares shall be Common Stock and 135,339,499 shares shall be Preferred Stock. 46,787,400 shares of Preferred Stock shall be designated "Series A Preferred Stock." 13,893,330 shares of Preferred Stock shall

> be designated “Series B-l Preferred Stock.” 27,030,040 shares of Preferred Stock shall be designated “Series B-2 Preferred Stock.” 17,764,230 shares of Preferred Stock shall be designated “Series C Preferred Stock.” 20,164,210 shares of Preferred Stock shall be designated “Series D Preferred Stock.” and 9,700,289 shares of Preferred Stock shall be designated “Series E Preferred Stock.”
>
> *October 2014 Restated COI of Square, Inc retrieved from VC Experts.*

Importantly, not all of these “authorized” shares are issued. The authorized number of shares is simply the maximum number of shares the company can issue in each class. Companies often provide a buffer of additional shares in case the round is larger than anticipated. For example, Square initially authorized 20.9 million Series D shares but issued only 20.2 million. We adjust for this using data on round amounts and valuations from commercial data sets. Specifically, we use the size of the most recent round in datasets to match the number of shares in the most recent round in the COI. We then estimate the number of shares issued in the latest round by dividing the amount of equity capital raised in the most recent round by the price paid per share. The price paid per share is typically reported in COI as the Original Issue Price (OIP). For example, to find the number of Series E shares outstanding after Square’s \$150 million round, we divide the amount raised by that round’s \$15.46 original issue price:

$$9.7 \text{ million} = \frac{\$150 \text{ million}}{\$15.46}. \tag{17}$$

If we do not have accurate round size data, we assume that all authorized shares were issued.[14] We only make this correction for the most recent round because COI subsequent to a financing round generally reduce the authorized preferred share number to match the number actually issued.

Once we have the number of each class of preferred, our next step is to determine the number of common shares. Although COIs give the number of authorized common shares and the total number of authorized shares, these numbers include ‘buffers’ of shares that are held aside for legal reasons. There is no way to determine the number of common shares issued from the COI.

Instead, we estimate the number of common shares using the post-money valuation. We first calculate the number of fully dilluted shares as the post-money valuation divided by the share price (the reverse

[14] This may lead us to underestimate overvaluation, as shown in Section 4.3.1, due to the investment amount effects described in Section 2.2.

of the postmoney valuation formula in Equation (1)). This fully-diluted number includes preferred shares, stock options (both unissued and issued), and common shares.

Next, we assume that 5% of the fully-diluted shares are unissued stock options. We do not have access to the actual stock option plans of companies (COIs and all available datasets are silent on this issue). Information on pre-IPO option issuance suggests this is a reasonable estimate. For example, Square issued 39 million in options in the two years after its Series E round, suggesting it had an option pool of 40 million or about 10% of its total number of shares.[15] Our industry sources confirm 5% is a reasonable and conservative number. In our robustness checks, we provide valuation ranges as we vary the unissued stock options between 0% and 10%. The results are similar.

The number of common shares is then set to the difference between the total number of shares and the sum of the preferred shares and unissued stock options. This implicitly assumes that issued stock options and warrants have the same value as common stock, an assumption that will decrease the overvaluation estimates.

Beyond the number of shares, COIs provide detailed descriptions of security cash flow rights. For example, Square's different classes not only have different levels of cash flows, they have cash flows that take different forms and special protections that trigger in different circumstances.

We coded the terms highlighted in Section 2.2 and all other material terms. We assigned letter codes to the most common and important terms for easy reference in tables and figures. We use 'd' for cumulative dividends, 'l' for liquidation multiples greater than one, 'p' for participation, 'r' for IPO ratchets, 's' for seniority over all other classes, and 'o' for automatic conversion exemptions that are strong enough to bind in all IPOs with less than 50% return. Many COI use intricate and non-standard structures outside of this classification. We calculate payoffs as written and have consulted with several lawyers, who are experts on venture capital and contract law, on the interpretation of specific terms and unclear cases.

[15] See https://www.sec.gov/Archives/edgar/data/1512673/000119312515378578/d937622ds1a.htm. Accessed January 27, 2017.

4 Unicorns are Overvalued

In this section, we estimate the value of unicorns and their classes of shares as of the date of these companies' latest funding round (as of February 2017). We first describe the prevalence of special financial terms among unicorns (Section 4.1). We then apply our valuation model to the sample of unicorns, taking into account these valuation terms (Section 4.2). Finally, we show that these overvaluation results are robust to different specifications (Section 4.3).

4.1 Special Contract Terms Used By Unicorns

We have shown that IPO ratchets and other contractual terms inflate valuations. Table 5 reports the frequency of these special terms used in our sample. These contractual terms reflect the result of negotiations between managers, existing shareholders, and the new investors. The diversity we observe gives further credence to the importance of contracting in VC-backed companies as discussed by Kaplan and Strömberg (2003), who use a sample of very early-stage companies.

The unicorns have many rounds of financing and we start by analyzing the contractual terms given to the latest, or new, investors. Table 5 shows that the new investors are on average senior to more than half of all the outstanding shares. While there is a large variation in the fraction of shares that are junior to new investors, this fraction is large for most of the unicorns in the sample. In 75% of cases, the new preferred shares are senior to at least 45% of other shares. In the median unicorn, new investors are senior to 60% of other shares. New preferred shares are always senior to all common shares. However, in 55 unicorns out of 116, new investors are also senior to some existing preferred investors. Moreover, in 36 unicorns, new investors are senior to all the existing investors. The most recent investors have liquidation preferences above one and participation in 5 and 11 companies, respectively. IPO ratchets are given to the most recent investors in 17 unicorns, typically with a 1X ratchet.[16]

We say that a new investor has a major protection if they have at least one of those terms: a liquidation multiple greater than 1, an IPO ratchet, seniority to all investors, participation, or an exemption from conversion in IPOs that result in returns below 0.5X. In 62 unicorns, about half of our sample, the most

[16] In a few cases, these terms vary over time, e.g. by giving IPO ratchet only for the next 18 months. In this case, we take the protection at our median exit (after 4 years) for these statistics.

recent investors had one of more major protection. This suggests that unicorns can be divided into two approximately equally-sized groups. Unicorns in the first group treat new investors the same way as they treat all their existing investors and do not give new investors any sweetened terms. Unicorns in the second group give new investors substantially better contractual terms. Investors in this second group often get several better terms at the same time.

We also analyze whether any investors, either existing or new investors, had special rights after the most recent funding round. Note that these contractual terms are typically agreed to at the time of the initial investment. We see a large variation in terms given to different investors in the same company. For example, while only five unicorns feature a liquidation multiple above 1X in the most recent round, 15 unicorns feature these high liquidation multiples for at least one investor. Only 11 unicorns gave their most recent investors participation, but 21 have given at least one of their investors participation. This variation can stem both from time variation in contractual terms and changes in company's fortunes. Overall, we find that 79, or two-thirds of all the unicorns in the sample, provide a major protection to at least one investor.

80 out of 116 unicorns feature enforceable conversion exemptions.[17] In all of these cases restrictions include minimum IPO proceeds to the company (either net or gross). Among these 68 unicorns, the average protection extends over the region of up to 46% of post-money valuation and the median extends up to 21% of post-money valuation. In 26 cases, this threshold is expressed in the form of a valuation requirement or a per-share payout, with median case requiring a return of 1X relative to the post-money valuation in the latest round. The IPO proceed requirements are usually small compared to the post-money value, averaging 5% of post-money value. Note, however, that IPO proceeds are generally much less than the valuation at the IPO. If a unicorn with a $1 billion post-money valuation gives an automatic conversion exemption in IPOs with proceeds below $200 million and IPO proceeds are equal to 25% of the pre-IPO valuation, that company cannot IPO if its pre-IPO value is less than $800 million or 0.8X.

Table 6 shows how these terms impact the financial returns preferred investors receive in different exits in our sample. We model the returns to the most recent class of investors for exits that are below the post-money valuation at which they invested. In M&A exits, VCs are very well protected. Even if the

[17] As discussed in Section 2.2, we do not count automatic conversion exemptions that will be overridden by a shareholder vote.

company's value falls to a tenth of the post-money valuation of the most recent round, the investor in that round get more than two thirds of their money back. In better M&A exits, the most recent series generally recover all of their investment.

In IPOs, the most recent investors' payoffs depend on whether they have protection against down IPOs, such as an IPO ratchet or an automatic conversion exemption. If they do, they fare well; if they do not, they undergo unfavorable conversion. The most recent series of preferred recovers 45% of their investment, if an IPO valuation is at 10% of the share price they invested at. In less severe down-IPOs, the most recent round may be less able to obstruct the IPO, yet the average losses to the most recent preferred are much less than the share price decline.

Holding exit value constant, the most recent investors do better in M&A exits than IPOs. Considering an exit at half of the most recent round's post-money valuation, the investors in that round recover all of their investment in an M&A in the median unicorn but only recover 50% of their investment in an IPO. This further supports the importance of automatic conversion exemption clauses and contractual features that make it easier or more difficult to override those clauses.

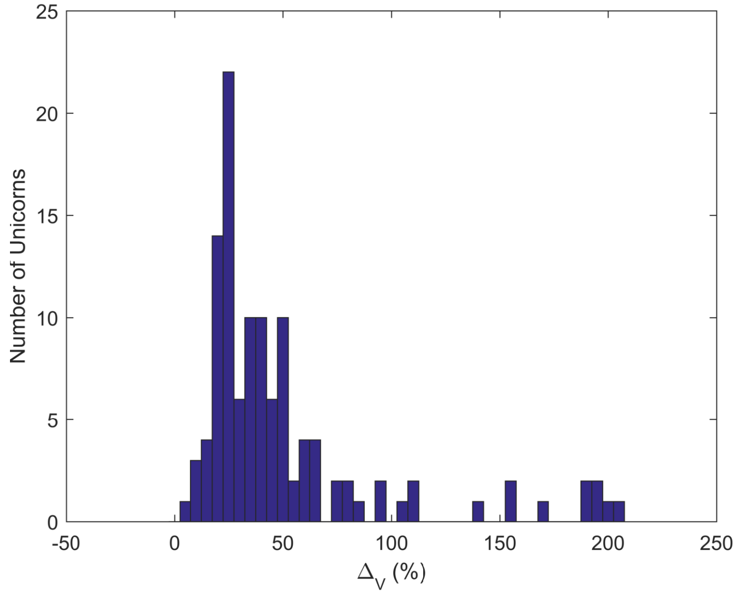
4.2 All Unicorns are Overvalued

Table 7 provides a summary of the results of our valuation model for the 116 unicorns in our sample on the day of their latest financing round. The average (median) post-money value of the unicorns in the sample is \$3.66 billion (\$1.6 billion), while the corresponding average (median) fair value implied by the model is only \$2.8 billion (\$1.1 billion). This results in a 51% (37%) overvaluation for the average (median) unicorn. Common shares even more overvalued, with the average (median) overvaluation of 62% (38%). There is a large variation in overvaluation. Figure 3 shows the distribution of overvaluation for the whole sample. 13 companies are overvalued by more than 100%.

Table 8 shows the model results for each of the company in our sample. We find that 53 of the 116 unicorns lose their unicorn status when calculated on a fair value basis. As in the Square example, the overvaluation comes because the most recently issued preferred shares have better cash flow rights. These rights come from a combination of higher liquidation values and rights that allow them to

Figure 3: Distribution of Unicorn Overvaluation

Figure 3 shows the distribution of overvaluation of the total value, Δ_V for the 64 unicorns in our sample. Overvaluation, Δ_V, is defined as the percentage that the post-money valuation overstates the company's fair value.



exercise these liquidation values. The overvaluation varies between different companies, because in companies where preferred shareholders have minimal extra rights, the overvaluation is lower.

The last columns of Table 8 lists the terms that impact each company. For example, the most recent investors in Uber have no rights to obstruct an IPO and in an IPO their preferred shares are automatically converted to common stock, along with all other shareholders. In this case, preferred stock is more valuable than common stock only in downside liquidation scenarios and the overvaluation is relatively small at 12%.

Snap stands out as an outlier as its most recently issued preferred stock has the same value as its common stock. This happens because Snap issued preferred with no liquidation preference in its most recent financing rounds, giving the VC investors the same payout as common equity holders. Industry sources confirm that Snap chose to issue common shares and was able to do so because of extremely strong investor appetite. Snap is the only company we found issuing common equity in this manner.

In unicorns where preferred shareholders have substantial extra rights, the misvaluation can be quite severe. We highlighted Square in Section 2.2, but other companies offer even more generous contractual terms. In July 2015, JustFab offered Series E investors an IPO ratchet, participation, and seniority. This combination of contractual terms resulted in an overvaluation of 110%, with the company's fair value being $475 million versus the reported post-money valuation of $1 billion. Datto offered its Series B investors in November 2015 an IPO ratchet, cumulative dividends, and a time-varying guaranteed M&A return of up to 41%, resulting in an overvaluation of 205%. Better Place offered investors cumulative dividends, the ability to obstruct down-IPOs, and seniority, resulting in a 196% overvaluation of common and a 358% overvaluation of preferred in its November 2011 Series C round (prior to it's May 2013 bankruptcy).

Special contractual terms have an even large impact on the overvaluation of common equity. In most cases, the model finds that common shares are more overvalued. Taken together, these results indicate that post-money valuations are substantially above fair values for many unicorns because of the preferential contractual terms these unicorns gave to their most recent investors.

4.3 Robustness

Our overvaluation results persist under many specifications. This section looks at how overvaluation is impacted by different assumptions. First, we examine our capital structure and contracting assumptions (Section 4.3.1). Second, we analyze our assumptions about model parameters (Section 4.3.2). Table 9 shows how overvaluation changes in the different scenarios we consider. Throughout this section, we report the impact on median overvaluation: overvaluation persists in all cases. The Online Appendix provides more details.

4.3.1 Capital Structure Assumptions

We need a number of assumptions to convert COIs to capital structure using the method described in Section 3.3. This section looks at how these assumptions impact valuation.

Valuation Errors. Because companies authorize more shares than they have actually issued, we use post-money valuations to calculate the total number of shares. We gather these valuations from multiple commercial data sets and cross check their accuracy with press reports and news articles.

Despite this, some post-money valuations may be misreported. Inaccurate post-money valuations have a large impact on fair values but a relatively small impact on overvaluation. If the post-money valuation is inflated, the fair value will be inflated by roughly same amount. For example, if the true post-money valuations were all 20% above our recorded numbers, overvaluation stays at 37%. If all of our post-money valuations were 20% below the true post-money valuations, median overvaluation decreases by 3% to 34%.

Investment Amount Errors. The number of shares authorized in a round is always at least as large as the round size, but in many cases companies authorize more than they issue. We address this by calculating the number of shares issued based off of the round size. This relies on accurate round sizes, which we again gather from multiple sources. In general, underestimating investment amounts exaggerates overvaluation because it means there are more highly valued preferred and fewer low valued common. As a robustness check, we consider the effect of assuming the entire round was issued – rather than the amount that was reported issued. This change decreases median overvaluation by 1% to 36%.

Unissued Options. Our analysis assumes that companies have a 5% pool of unissued stock options at the time of their financing and that this is included in the post-money valuation. This option pool raises overvaluation as unissued options are not included in fair value. Data from J. Thelander Consulting suggests that the median option pool size is 16% for firms with $90 million or more in financing. Although our knowledge here is limited, the intuition that unicorns are still actively issuing options is confirmed from the S-1 data of now-public unicorns, where, for example, Square issued 38 million options implying at least a 10% option pool. The problems here are that these are just anecdotes, and we do not know if these options came from an option pool. We use a lower number to be conservative. If we assume there is no option pool, overvaluation at the company level falls by 7% to 30%. Conversely, assuming a 10% option pool increases overvaluation to 44%.

Option Strike Prices. We assume issued stock options have the same value as common stock, as we have no data on option strike prices. This assumption is conservative, as ignoring the strike price inflates fair value by overvaluing options. To see the impact of including stock options, we can assume that 25% of the company's common stock is in the form of options that have a strike price equal to one third the most recent round's price. This scenario leads to overvaluation of 43%.

Debt. We assume that the companies in our sample do not issue significant amounts of debt. in practice, not much debt is issued and debt that is issued generally has a significant option-like component. This follows naturally from our volatility assumption, which effectively shuts unicorns out of the credit market. Under the pricing measure, high volatility implies a very large convexity correction: using 90% volatility, the median unicorn loses 85% of its value over the next five years. These value losses are not conducive to significant indebtedness. Assuming unicorns have debt with a repayment at exit equal to 7% of their present fair value gives us 5% leverage. Adding in this level of leverage reduces median overvaluation to 30%. Higher debt levels reduce leverage further: a repayment at exit equal to 14% of present fair value gives us 10% leverage and reduces median overvaluation to 26%.

Indifference to Future Financing. We assume that future rounds do not transfer value between investors. This is clearly untrue in extreme cases, such as so-called cram down rounds where preferred equity is converted into common shares and loses its special rights. Even thought these rounds are rare, looking at this extreme case enables us to approximate the impact of these terms. If we assume that cram down rounds happen 25% of the time (the preferred investors lose their rights 20% of the time, clearly an extreme assumption) overvaluation is reduced to 28%. Although this is a substantial fall in overvaluation, our assumption here is undoubtedly conservative.

Hold up in IPOs. We have assumed that preferred investors that are not automatically converted can hold up an IPO and that they choose to do so. Alternatively, we can assume investors do not hold up an IPO. This reduces the payoff to the most recent investor and so reduces overvaluation. If we assume that these investors can hold up the IPO 50% of the time when it benefits them, median overvaluation falls to 32%. If we assume that these investors always convert in IPOs, even if this would be value losing for them, median overvaluation falls to 27%.

4.3.2 Model Parameter Assumptions

Section 2.4 showed how varying parameters impacted the results for our simple unicorn example. When we perform this analysis for the entire sample of unicorns, we find similar results.

Volatility. Volatility has a non-monotonic relationship with overvaluation. It increases the likelihood of liquidation preferences being claimed, but reduces the value in the scenarios when they are claimed. Increasing volatility to 1.1 reduces overvaluation to 33%, decreasing volatility to 0.7 decreases overvaluation to 36%, and decreasing volatility to 0.5 reduces overvaluation to 31%.

Exit Rate. Higher exit rates increase overvaluation for most companies. This is not the case for a small number of companies with time sensitive contracts, which demand very large payouts with delayed exits. In our sample, the former effect dominates. Increasing the exit rate to 0.5 increases overvaluation to 39%. Reducing the exit rate to 0.125 reduces the overvaluation to 28%

M&A and IPO Exit Probability. IPOs can trigger automatic conversion which has a large impact on payoff. Our IPO distribution assumption is based on the IPO rate observed in the data. As a robustness check, we can assume that IPOs happen for all exits above $1 billion and all other exits are trade sales. This increases median overvaluation to 49%. Alternatively, we could assume that IPOs happen in exactly one half of unicorn exits. This increases median overvaluation to 38%.

IPO Proceeds. Changing the IPO proceeds has a relatively small impact on overvaluation. If we assume that IPO proceeds are 10% of the IPO amount, overvaluation rises to 43% as fewer automatic conversion terms are triggered. Alternatively, if we assume IPO proceeds are 50% of the IPO amount, overvaluation falls to 34%.

Risk-free Rate. A lower risk free rate increases overvaluation by increasing the value of liquidation preferences and increasing the chance they are used. Using a risk free rate of zero increases overvaluation to 41%, increasing the risk free rate to 5% decreases overvaluation to 33%.

5 Discussion

Our results speak to the the importance of information availability to investors, limited partners, and employees. The valuation of securities is extremely sensitive to the precise contractual terms given to investors. While a small group of privileged investors are aware of these terms and in fact negotiated for them, many others with direct financial stakes cannot even view them. Although COIs are in principle publicly available, almost all startup employees and many investors are unaware of their intricacies and do not understand the valuation implications. Examples we have given earlier on mutual funds and secondary share trading platforms further support this conclusion.

This lack of information is particularly troublesome because of the large variation in overvaluation between companies. There is essentially no reporting of the terms of venture capital deals, yet small variations in terms can correspond to large variations in value. Table 10 illustrates the impact on valuation of adding a strong Qualified IPO restrictions that prevent down IPOs for the ten most valuable unicorns in our sample. Giving the most recent investors in Uber a right to block an IPO increases an overvaluation in Uber from 12% to 52%. If this contractual term exists, our model predicts that Uber's fair value drops from around $61 billion to just $45 billion. The only company that is spared from the rout is Snap, where preferred investors have no real rights in either M&A or IPO deals. On average, this term increases the overvaluation of this ten companies from 22% to 71%.[18]

The Securities and Exchange Commission has similar concerns about unicorn valuations. As Chairwoman Mary Jo White said "In the unicorn context, there is a worry that the tail may wag the horn, so to speak, on valuation disclosures. The concern is whether the prestige associated with reaching a sky high valuation fast drives companies to try to appear more valuable than they actually are."[19]" To provide an illustration of that sentiment, consider SpaceX, one of the ten most valuagle unicorns in our dataset. In August 2008, SpaceX raised money for its satellite launch and space travel services. Despite significant falls in the NASDAQ and the third failed test flight of their satellite launch service,

[18]It is important to note that we don't have access to all the contracts between investors and companies. For example, companies often sign side letters with some of the investors that contain additional guarantees. While our legal sources suggest that provisions such as strong Qualified IPO restrictions are unlikely to appear in such side letters and, even if they were, it would be unclear whether they would be upheld in court, we have not seen these side letters to reach a conclusive decision.

[19]See https://www.sec.gov/news/speech/chair-white-silicon-valley-initiative-3-31-16.html. Accessed January 27, 2017.

its Series D round was an “up” round at $3.88 per share, above the March 2007 Series C price of $3.00 per share.

SpaceX has since gone on to be a successful company, with its most recent round stratospheric price of $77.46 per share. However, we argue that the 2008 price increase was due to the preferential treatment of the Series D investors and that the share price increase came about despite a fall in the company’s fair value. Table 11 shows SpaceX’s cap table at the time of its Series D round. Before the 2008 Series D round, the company’s share price had been increasing consistently: $1, $2, $3. The Series D round saw the price increase to $3.88, but the investors who gave that price were promised twice their money back in the event of a sale, with that promise senior to all other shareholders. Our model shows that this type of contractual protection is extremely valuable and that it dramatically increased SpaceX’s post-money valuation. Because SpaceX made generous promises to the new investors, what should have been a crushing down round became an up round, at least in terms of the share price and post-money valuation.

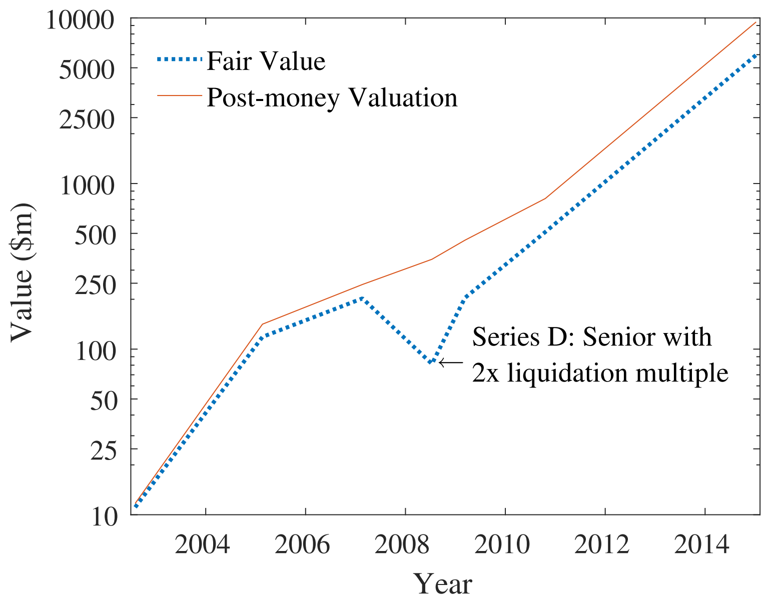
Figure 4 plots out the path of SpaceX’s value over time. The dotted line plots the consistently increasing post-money valuation. The solid line plots the model-implied fair value share price of common shares. It shows significant volatility, dropping dramatically in 2008 and then recovering. This high volatility during the financial crisis seems closer to what one would expect for a risky space exploration company.

We see similar patterns in SpaceX’s Series E round, which offered investors participation, the same seniority as Series D, and most importantly allowed investors to redeem their shares for 2x their fair market value in six years. Promising an investor twice her money back increases the price she is willing to pay, which increases a company’s post-money valuation but does not change its underlying business.

Importantly, our discussion does not imply that these terms were given for the purpose of manipulating SpaceX’s value. The changes in contractual terms may be due to other factors, for example, due to increased levels of asymmetric information or increased investor risk aversion. However, this example vividly illustrates the concern, shared by the SEC, that poorly performing companies or companies facing tough external environment may use more generous securities in a way that dramatically exaggerates their valuations.

Figure 4: SpaceX Common Share Price

Figure 4 shows how SpaceX's common share price evolves over time when taken as the most recent share price (dotted) or as the share price emerging from our capital structure model (solid). Common share prices are calculated so that the most recent VC round is fairly priced, where cash flows are taken from the COI and returns are simulated using a geometric Brownian motion with volatility of 0.9 and drift 0.025 under the risk-neutral measure, that exits at a 0.25 exponential rate. The value is reported using a logarithmic scale.



IPO ratchets, automatic conversion vetos, and liquidation preferences have come into force relatively infrequently, because they protect against highly unfavorable scenarios. However, if the valuation of VC-backed companies experiences a dramatic correction, as in the early 2000s, many of these contractual features would be in the money and would be exercised. As these contractual features provide downside protection, which is valuable for new investors and hurts earlier investors and common shareholders, a substantial correction of VC-backed companies may lead to a substantial wealth transfer between different groups of investors and leave employees holding the wrong end of the stick.

6 Conclusion

Valuation of real and financial assets is at the core of finance. In this paper, we develop a parsimonious modeling framework to value unicorns: young, innovative, and highly-valued companies backed by venture capitalists. We apply our model to value 64 unicorns, private VC-backed companies with a reported post-money valuation over $1 billion, at the time of the funding rounds. We find the fair value of these companies and the value of each of the securities they issued. The post-money valuation metric overvalues all unicorns, but the degree of overvaluation varies dramatically from one unicorn to another. While on average all the unicorns in our sample are overvalued by 37%, some unicorns are overvalued by only 11%–22%, while others are overvalued by more than 100%. Our results suggest that more attention should be paid to terms the contractual terms between investors and companies.

Our analysis can in principle be applied to all VC-backed companies, not only unicorns. Studying the valuation of early-stage VC-backed companies will enable us to understand which contractual terms are particularly important for an early stage company and guide the founders and investors. The valuation implications for all the VC-backed companies, like the implications for unicorns, are likely to be substantial and constitute an important avenue for future investigation.

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Table 1: Impact of Contract Terms on Fair Value

Table 1 shows how contract terms impact the fair value that corresponds to a post-money valuation of $1 billion. The table considers the fair value of the company that fairly prices a $100 million investment with a post-money valuation of $1b and different terms. The Company columns report the post-money valuation of the new round (PMV), the fair value of the company that makes that round fairly priced (FV), and the percentage by which the post-money valuation overstates the fair value (Δ_V). The Common Share columns report the value of a common share implied by the post-money valuation (PMV), the fair value of a common share if the round was correctly priced (FV), and the percentage the post-money valuation formula overstates the value of a common share (Δ_C). We simulate asset returns using a geometric Brownian motion with volatility, σ, 0.9 and drift, r_f, 0.025 under the risk-neutral measure, for a company which exits with annual Poisson intensity, λ, 0.25.

	Company			Common Share		
Scenario	PMV ($m)	FV ($m)	Δ_V	PMV ($m)	FV ($m)	Δ_C
Baseline	1,000	771	30%	1	0.78	28%
Liquidation Multiple						
1.25X	1,000	704	42%	1	0.70	43%
1.5X	1,000	637	57%	1	0.62	61%
2X	1,000	514	94%	1	0.48	110%
Option Pool						
0%	1,000	810	23%	1	0.78	28%
10%	1,000	732	37%	1	0.78	28%
Seniority						
Junior	1,000	811	23%	1	0.82	22%
Senior	1,000	736	36%	1	0.74	35%
Participation						
with no cap	1,000	652	53%	1	0.64	57%
with 2.5X cap	1,000	659	52%	1	0.65	55%
IPO Ratchet						
at 1X	1,000	639	56%	1	0.62	60%
at 1.25X	1,000	572	75%	1	0.54	84%
at 1.5X	1,000	508	97%	1	0.47	114%
Automatic Conversion Veto						
below 1X	1,000	646	55%	1	0.63	59%
below 0.75X	1,000	650	54%	1	0.63	58%
below 0.5X	1,000	678	48%	1	0.66	50%
Investment Amount						
$400 million in round 2	1,000	874	14%	1	0.85	17%
$10 million in round 2	1,000	695	44%	1	0.72	39%
$400 million in round 1	1,000	835	20%	1	0.83	20%
$10 million in round 1	1,000	740	35%	1	0.75	33%

Table 2: Square Financing Rounds as of October 2014

This table provides the financing Square received up to and including its $150 million Series E round in October 2014. Round dates and (post-money) valuations are from CB Insights, public disclosures, and VentureSource. Investment amounts, share numbers, and payouts are from Square's COI. The minimum payout for sale/failure is set to the liquidation preference and for IPO is set to the IPO ratchet level, if any. PMV stands for post-money valuation, and OIP is for original issue price.

Series	Issue Date	PMV at Issue ($m)	Amount ($m)	Shares (m)	OIP ($)	Minimum Payout	
						Sale/Failure	IPO
Series E	Oct 2014	6,000	150	10	15.46	15.46	18.56
Series D	Sep 2012	3,270	222	20	11.01	11.01	-
Series C	Jun 2011	1,600	103	18	5.80	5.80	-
Series B-2	Mar 2011	233	26	27	0.95	0.95	-
Series B-1	Dec 2010	136	10	14	0.72	0.72	-
Series A	Dec 2009	45	10	47	0.22	0.22	-
Issued Common and Options		-	-	233	-	-	-
Unissued Options		-	-	19	-	-	-

Table 3: Square's Security Values at October 2014

Table 3 lists the post-money valuation and fair value of each class of Square's shares, immediately following the company's October 2014, $150 million Series E round. Each class of share is priced based on a fair value of Square that correctly prices the Series E round. The Share Price columns report the share price on a post-money valuation (PMV) and fair value (FV) basis. The Class Value columns repeat that for the entire class of shares. The final column the percentage the post-money valuation formula overstates the value of each class of share (Δ). We simulate asset returns using a geometric Brownian motion with volatility, σ, 0.9 and drift, r_f, 0.025 under the risk-neutral measure, for a company which exits with annual Poisson intensity, λ, 0.25.

Security	Shares (m)	Share Price ($)		Class Value ($m)		Δ
		PMV	FV	PMV	FV	
Series E	10	15.46	15.46	150	150	0%
Series D	20	15.46	7.17	312	145	116%
Series C	18	15.46	6.23	275	111	148%
Series B-2	27	15.46	5.66	418	153	173%
Series B-1	14	15.46	5.65	215	78	174%
Series A	47	15.46	5.63	723	263	175%
Issued Common and Options	233	15.46	5.62	3,608	1,311	175%
Unissued Options	19	15.46	0.00	300	-	-
Total		15.46	6.00	6,000	2,211	171%

Table 4: Sample of Unicorns

This table provides summary statistics for our main sample and the entire sample, which consists of past and present U.S. unicorns founded after 1994 with a VC round after 2004. We compare this to the subsample of unicorns we have collected data on. All data are from VentureSource, except for the number of COIs, which is from our files.

	Total Sample	Main Sample	COI Incomplete	COI Unavailable
Count	146	116	18	12
Status				
Private	107	85	14	8
IPO	26	21	3	2
Acquired	11	8	1	2
Failed	2	2	0	0
Founded	2007.4	2007.8	2006.6	2004.7
Based in California	66%	71%	50%	42%
Total financing ($m)	737	716	1,040	487
Number of rounds	6.6	6.8	6.6	4.8
Number of COIs we have	11.3	12.4	11.6	0.0
Last VC round				
Date	2015.2	2015.2	2014.9	2015.5
PMV ($m)	2,854	2,687	5,307	1,152
Round size ($m)	202			

Table 5: Prevalence of Special Contract Terms Among Unicorns

This table presents data on the prevalence of certain contractual terms in our sample. All data are from the most recent COI. Rounds is the number of equity rounds. Seniority classes is the number of seniority classes (for example, 2 for a company with common equity and one class of Series A Preferred). Major protections are the protections given letter codes in the Code column: seniority to all investors, a liquidation multiple greater than 1, participation, cumulative dividends, an IPO ratchet, or if they are the most recent investor and are exempted from conversion in IPOs resulting in returns below 0.5X returns.

Code	Code	Count	Mean	25th pct	50th pct	75th pct
Number of unicorns		116				
Preferences Given to Latest Investors						
% of shares new investors senior to			0.64	0.45	0.60	0.86
Senior to some investors		55	0.47			
Senior to all investors	**s**	36	0.31			
Liquidation multiple > 1	**l**	5	0.04			
Participation	**p**	11	0.09			
Cumulative dividends	**d**	6	0.05			
for those, level			0.09	0.08	0.08	0.09
IPO Ratchet	**r**	17	0.15			
for those, level			1.26	1.00	1.00	1.49
Any major protection		62	0.53			
Preferences Given to at Least One Investor						
Seniority	**s**	53	0.46			
Liquidation multiple > 1	**l**	15	0.13			
Participation	**p**	21	0.18			
Cumulative dividends	**d**	12	0.10			
for those, level			0.10	0.07	0.08	0.12
IPO Ratchet	**r**	20	0.17			
for those, level			1.36	1.00	1.23	1.58
Any major protection		79	0.68			
Automatic Conversion Exemptions						
Any exemption		80	0.69			
for those, valuation needed ($m)			894	200	400	924
for those, valuation / PMV			0.46	0.11	0.21	0.59
Require valuation		26	0.22			
for those, valuation needed ($m)			2,097	848	1,792	3,190
for those, valuation / PMV			1.06	0.57	1.03	1.50
Require proceeds		80	0.69			
for those, proceeds needed ($m)			91	50	50	100
for those, proceeds / PMV			0.05	0.02	0.04	0.06
Exemption binds in < 0.5X IPOs	**o**	23	0.20			

Table 6: Returns to Most Recent Class of Preferred in Down Exits

Table 6 presents statistics on the distribution of returns realized by the most recent class of preferred investors in our main sample of 116 unicorns. We consider exits at a discount to each round's post-money share price. All data are from the most recent COI.

	Mean	25th pct	50th pct	75th pct
Return to most recent round in M&A exit				
at 10% of PMV	68%	49%	64%	91%
at 25% of PMV	100%	100%	100%	100%
at 50% of PMV	105%	100%	100%	100%
Return to most recent round in IPO exit				
at 10% of PMV	45%	10%	44%	73%
at 25% of PMV	63%	25%	28%	100%
at 50% of PMV	75%	50%	50%	100%

Table 7: Summary of Unicorns' Fair Values and Post-money Valuations

Table 7 presents the post-money valuation (PMV), fair value (FV), the percentage PMV overstates FV (Δ_V), and the percentage PMV overstates the common share price (Δ_C) for the unicorns in our sample. This table presents the mean and percentiles of the distributions of values and overvaluations. Contractual terms are gathered from COIs. The Special Terms column uses the letter codes for contractual terms from Table 5. Model-implied values are the security prices that match a fairly priced round. We simulate asset returns using a geometric Brownian motion with volatility, σ, 0.9 and drift, r_f, 0.025 under the risk-neutral measure, for a company which exits with annual Poisson intensity, λ, 0.25.

	Count	Mean	Min	25th pct	50th pct	75th pct	Max
PMV ($m)	116	3,660	1,000	1,165	1,611	3,000	68,000
FV ($m)	116	2,861	328	800	1,082	2,227	60,597
Δ_V	116	51%	5%	24%	37%	55%	205%
Δ_C	116	62%	0%	23%	38%	63%	358%

Table 8: Detailed Unicorns' Fair Values and Post-money Valuations Table 8 presents company-level post-money valuations (PMV), fair values (FV), and overvaluations (Δ_V and Δ_C) for the common share values and total values of the unicorns in our sample. Contractual terms are gathered from COIs. The Special Terms column uses the letter codes for contractual terms from Table 5. Model-implied values are the security prices that match a fairly priced round. We simulate asset returns using a geometric Brownian motion with volatility, σ, 0.9 and drift, r_f, 0.025 under the risk-neutral measure, for a company which exits with annual Poisson intensity, λ, 0.25.

		Valuation ($b)			Common Price PS ($)			Special Terms	
Company	Rd Date	PMV	FV	Δ_V	PMV	FV	Δ_C	Last Rd	Any Rd
23andMe	Jun 2016	1.1	0.8	40%	10.83	7.67	41%	s	s
Actifio	Jul 2015	1.1	0.6	93%	12.63	6.21	103%	lr	lr
Adaptive Biotech	May 2015	1.0	0.8	26%	8.97	6.89	30%	s	s
Age of Learning	Mar 2015	1.0	0.7	44%	4.22	2.88	47%	s	
Airbnb	Dec 2016	30.0	26.1	15%	105.00	94.96	11%		
Anaplan	Dec 2015	1.1	0.9	23%	10.10	8.24	23%		
AppDirect	Sep 2015	1.4	0.9	46%	19.67	13.22	49%	s	s
AppDynamics	Jan 2016	1.9	1.3	48%	13.71	9.09	51%	or	or
Appnexus	Aug 2016	1.5	1.0	48%	26.00	1.59	63%		lrs
Apttus	Feb 2016	1.6	1.3	23%	12.61	10.38	22%		
Automattic	Apr 2016	1.2	0.9	31%	18.00	13.81	30%		s
Avant	Oct 2015	2.0	1.6	26%	102.44	78.25	31%		
Better Place	Dec 2011	2.3	0.8	196%	4.54	0.99	358%	dos	dos
Bloom Energy	Jun 2011	3.0	2.7	12%	25.76	23.16	11%		l
Blue Apron	May 2015	2.1	1.6	37%	13.33	10.00	33%	s	s
Box	Jul 2014	2.6	0.9	195%	20.00	5.57	259%	lrs	lprs
Buzzfeed	Nov 2016	1.6	1.1	52%	45.04	2.75	64%	rs	rs
Cloudera	May 2014	4.1	3.5	19%	30.92	26.73	16%		
CloudFlare	Jun 2015	3.2	1.6	103%	6.13	3.03	102%	os	os
Compass	Jul 2016	1.0	0.3	202%	42.63	10.69	299%	r	r
Coupons.com	Mar 2011	1.0	0.8	19%	10.99	9.16	20%		s
Credit Karma	Jun 2015	3.5	2.8	27%	14.07	11.49	22%		s
Cylance	Jun 2016	1.0	0.7	49%	22.23	14.63	52%	o	o

Table 8: **Detailed Unicorns Fair Values and Post-money Valuations (Continued)**

Company	Rd Date	Valuation ($b) PMV	FV	Δ_V	Common Price PS ($) PMV	FV	Δ_C	Special Terms Last Rd	Any Rd
Datto	Oct 2015	1.0	0.3	205%	85.27	23.53	262%	dlr	dlr
Demand Media	Feb 2008	1.2	0.4	188%	6.00	1.36	341%	dos	dos
Docker	Apr 2015	1.1	0.9	26%	24.44	19.60	25%		
DocuSign	Apr 2015	3.0	2.2	35%	19.09	14.03	36%	p	lp
Domo	Mar 2016	3.8	3.2	19%	7.80	6.78	15%		s
DraftKings	Aug 2015	2.0	1.5	35%	7.67	5.36	43%	o	os
Dropbox	Jan 2014	10.4	8.6	21%	19.10	16.44	16%		
Eventbrite	Feb 2014	1.2	0.9	27%	16.38	13.13	25%		s
Evernote	May 2015	1.7	1.1	54%	16.00	10.07	59%	o	dop
Fab.com	Feb 2014	1.2	1.0	19%	7.48	6.25	20%		
Fanatics	Feb 2016	2.7	1.7	64%	9.00	4.99	81%	os	os
FireEye	Dec 2012	1.3	0.8	48%	10.53	7.29	44%		
Flatiron Health	Jan 2016	1.2	1.0	21%	6.56	5.47	20%		
Flipboard	Jun 2015	1.3	0.7	96%	2.21	1.03	114%	lr	lr
Forescout Tech	Nov 2015	1.0	0.6	73%	11.87	6.17	92%	os	ops
Github	Jul 2015	2.0	1.6	22%	11.17	9.32	20%		
Good Technlgy.	May 2014	1.2	0.5	155%	4.11	1.34	207%	pr	pr
Groupon	Dec 2010	4.8	4.1	17%	31.59	27.73	14%	s	s
HomeAway	May 2011	1.7	0.8	110%	16.33	5.86	179%	lrs	dlprs
Hortonworks	Jul 2014	1.4	1.0	33%	12.19	9.14	33%		
Houzz	May 2016	2.3	1.8	28%	7.49	6.06	24%		
Human Longevity	Jun 2015	1.9	1.5	23%	12.78	10.57	21%		
Illumio	Apr 2015	1.0	0.8	30%	3.21	2.50	28%		
Insidesales.com	Jan 2017	1.7	1.4	25%	4.82	3.92	23%		
Instacart	Dec 2014	2.0	1.6	23%	66.55	55.17	21%		
Intarcia Therapeutics	Sep 2016	3.9	2.8	39%	60.00	43.00	40%	s	s
Intrexon	Mar 2013	1.1	0.6	82%	7.88	3.16	149%	dps	dps

Table 8: **Detailed Unicorns Fair Values and Post-money Valuations (Continued)**

		Valuation ($b)			Common Price PS ($)			Special Terms	
Company	Rd Date	PMV	FV	Δ_V	PMV	FV	Δ_C	Last Rd	Any Rd
Jasper Wireless	Mar 2014	1.4	0.8	74%	15.25	8.70	75%	s	s
Jawbone	Dec 2015	1.5	1.3	13%	1.95	1.43	37%		lps
Jet.com	Jan 2016	1.6	1.3	24%	4.99	3.65	37%	o	do
JustFab	Jul 2014	1.0	0.5	110%	19.39	6.65	191%	prs	lprs
Kabam	Aug 2014	1.0	0.6	62%	1.96	1.13	74%	os	os
Kabbage	Jun 2015	1.0	0.5	90%	18.52	8.65	114%	ds	ds
LendingClub	Apr 2014	3.7	2.5	50%	20.34	13.93	46%	p	p
LinkedIn	Jun 2008	1.0	0.6	61%	11.47	7.08	62%	o	o
Lookout	Sep 2014	1.7	1.4	23%	11.42	9.40	22%		
Lyft	Dec 2015	5.5	4.9	11%	26.79	24.40	10%		
Lynda.com	Dec 2014	1.0	0.7	39%	4.75	3.23	47%	r	r
Machine Zone	Aug 2016	5.6	4.4	26%	3.87	3.13	23%		
Magic Leap	Dec 2015	4.5	3.0	50%	23.03	14.08	64%	os	os
MarkLogic	Apr 2015	1.2	0.9	34%	11.61	8.83	32%		s
Medallia	Sep 2016	1.3	1.0	28%	11.14	8.73	28%		s
MediaMath	May 2014	1.1	0.6	79%	5.42	2.97	82%	os	dos
Moderna	Aug 2016	4.7	3.9	21%	8.78	7.36	19%	s	ds
MongoDB	Dec 2014	2.4	1.9	23%	16.72	13.96	20%		
MuleSoft	May 2015	1.5	1.1	40%	11.23	7.86	43%	p	p
New Relic	Apr 2014	1.5	1.0	46%	28.93	19.78	46%		s
Nextdoor	Aug 2014	1.1	0.9	25%	14.50	11.76	23%		
NJOY	Oct 2015	1.3	0.8	66%	0.15	0.08	91%	d	ds
Nutanix	Aug 2014	2.0	0.8	156%	13.40	4.46	200%	rs	lrs
OfferUp	Aug 2016	1.3	0.9	38%	6.70	4.86	38%	s	s
Okta	Jul 2015	1.2	1.0	25%	12.02	9.79	23%		
OnLive	Mar 2012	1.9	1.3	43%	7.50	5.17	45%	s	ps
Oscar	Feb 2016	2.7	1.9	43%	6.75	4.53	49%	r	r

Table 8: Detailed Unicorns Fair Values and Post-money Valuations (Continued)

		Valuation ($b)			Common Price PS ($)			Special Terms	
Company	Rd Date	PMV	FV	Δ_V	PMV	FV	Δ_C	Last Rd	Any Rd
Palantir	Dec 2015	20.5	17.8	15%	11.38	10.29	11%		
Pinterest	Apr 2016	11.4	9.4	21%	7.18	6.14	17%		
Pivotal	May 2016	3.3	2.2	46%	5.20	3.29	58%	rs	rs
Prosper	Feb 2016	1.9	1.2	56%	6.91	4.35	59%	o	ops
Proteus Dgtl Hlth	Apr 2016	1.5	1.1	33%	15.80	11.11	42%	p	ps
PURE Storage	Mar 2015	2.9	2.4	21%	15.73	13.36	18%		
Quanergy Systems	Mar 2016	1.6	0.9	86%	115.42	61.95	86%	os	os
SimpliVity	Mar 2015	1.2	0.8	41%	5.23	3.55	47%	o	o
Snap	Oct 2016	20.0	19.0	5%	30.72	30.72	0%		
Social Finance	Jul 2015	3.6	2.8	27%	15.78	11.37	39%	o	dlo
SolarCity	Mar 2012	1.9	0.6	188%	23.92	7.44	222%	rs	rs
Solyndra	Jul 2009	1.5	0.9	60%	3.96	1.48	168%	ops	ops
SpaceX	Jan 2015	10.5	6.4	64%	77.46	46.38	67%	o	los
Sprinklr	Jun 2016	1.8	1.3	36%	9.00	6.69	35%		p
Square	Sep 2014	6.0	2.2	171%	15.46	5.62	175%	rs	rs
Stemcentrx	Aug 2015	7.1	5.9	19%	23.04	20.01	15%		r
Sunrun	Aug 2014	1.3	0.8	63%	13.83	7.97	74%	os	os
TangoMe	Mar 2014	1.1	0.8	39%	4.28	2.81	52%	os	os
Tanium	Dec 2015	3.7	2.8	31%	4.96	3.92	27%		
The Honest Co	Aug 2015	1.7	1.2	40%	45.76	32.36	41%	r	lr
Theranos	Oct 2015	10.5	8.0	31%	20.00	15.60	28%	p	ps
Thumbtack	Sep 2015	1.3	1.0	24%	8.51	6.95	22%		
Twilio	Apr 2015	1.1	0.9	26%	11.31	8.95	26%		
Twitter	Nov 2011	9.3	7.6	21%	16.09	13.83	16%		s
Uber	May 2016	68.0	60.6	12%	48.77	45.17	8%		lr
Udacity	Nov 2015	1.0	0.7	35%	7.55	5.65	34%	s	s
Unity Software	Apr 2016	1.5	1.1	37%	14.18	10.35	37%		

Table 8: Detailed Unicorns Fair Values and Post-money Valuations (Continued)

		Valuation ($b)			Common Price PS ($)			Special Terms	
Company	Rd Date	PMV	FV	Δ_V	PMV	FV	Δ_C	Last Rd	Any Rd
Vox Media	Sep 2015	1.1	0.7	49%	7.34	4.43	66%	p	p
Warby Parker	Apr 2015	1.2	1.0	25%	11.49	9.30	24%		
WeWork	Mar 2016	16.0	13.5	18%	50.19	44.00	14%		s
WhatsApp	Jul 2013	2.7	1.7	60%	6.53	4.19	56%	p	p
Workday	Oct 2011	1.8	1.2	52%	13.26	8.69	53%	s	ps
Zenefits	May 2015	4.5	3.7	20%	14.90	12.75	17%		
ZenPayroll	Dec 2015	1.1	0.9	26%	5.02	4.04	24%		
Zocdoc	Jul 2015	1.8	1.3	34%	29.29	21.17	38%		p
Zoox	Sep 2016	1.6	1.1	39%	7.34	5.16	42%		
Zscaler	Jul 2015	1.1	0.7	51%	5.98	3.82	56%	o	o
Zulily	Nov 2012	1.1	0.8	38%	2.07	1.52	37%		
Zynga	Apr 2011	9.0	7.3	24%	14.03	11.79	19%	s	s

Table 9: Valuations Under Robustness Checks

Table 9 shows how the mean, median, and quartiles of overvaluation change in different scenarios. These statistics are calculated across a sample of 116 unicorns using data from COIs. We estimate overvaluation by simulating asset returns using a geometric Brownian motion with volatility, σ, 0.9 and drift, r_f, 0.025 under the risk-neutral measure, for a company which exits with annual Poisson intensity, λ, 0.25.

	Mean	Min	25th pct	50th pct	75th pct	Max
Baseline	51%	5%	24%	37%	55%	205%
Valuation Errors.						
Real PMV 20% above reported	56%	5%	25%	37%	59%	264%
Real PMV 20% below reported	43%	5%	21%	34%	49%	170%
Investment Amount.						
Taken from COI.	50%	5%	24%	36%	57%	213%
Unissued Options.						
0% ESOP	45%	0%	18%	30%	48%	199%
10% ESOP	58%	11%	30%	44%	62%	213%
Option Strike Prices.	58%	10%	31%	43%	62%	211%
Debt.						
5% Leverage	42%	5%	20%	30%	44%	184%
10% Leverage	36%	5%	18%	26%	39%	166%
Indifference to Future Financing.						
Cramdowns 10% of the time	43%	5%	22%	32%	47%	171%
Cramdowns 20% of the time	36%	5%	19%	28%	40%	142%
Hold up in IPOs.						
Exercised 50% of the time	46%	5%	23%	32%	46%	220%
Never exercised	42%	5%	22%	27%	38%	253%
Volatility.						
$\sigma = 0.5$	76%	5%	20%	31%	64%	735%
$\sigma = 0.7$	62%	5%	24%	36%	62%	361%
$\sigma = 1.1$	43%	5%	22%	33%	49%	152%
Exit Rate.						
$\lambda = 0.5$	66%	5%	25%	39%	69%	357%
$\lambda = 0.125$	40%	5%	20%	28%	40%	301%
M&A and IPO Exits.						
$p^{IPO}(X) = \mathbb{I}[X > \$1b]$	58%	5%	36%	49%	66%	235%
$p^{IPO}(X) = 50\%$	52%	5%	24%	38%	58%	209%
IPO Proceeds.						
IPO proceeds of $0.1X(T)$	54%	5%	25%	43%	62%	219%
IPO proceeds of $0.5X(T)$	50%	5%	23%	34%	53%	234%
Risk-free Rate.						
$r_f = 0\%$	58%	5%	26%	41%	62%	241%
$r_f = 5\%$	45%	5%	22%	33%	49%	193%

Table 10: Impact of Hypothetical Qualified IPO Restrictions on Overvaluation

Table 10 considers how Qualified IPO restrictions might impact the fair values of the largest VC backed companies. The first column lists the post-money valuation (PMV) of these companies as of their most recent round. The two columns under "Based on COI" both consider the cash flows outlined in the COI and list the fair values (FV) that cause the most recent round to be fairly priced and the the percentage by which the post-money valuation overstates the fair value (Δ_V). The two columns under "Qialified IPO Restrictions" repeat this exercise, but calculate the fair value under the assumption that the most recent investors had a veto over down-IPOs. We simulate asset returns using a geometric Brownian motion with volatility, σ, 0.9 and drift, r_f, 0.025 under the risk-neutral measure, for a company which exits with annual Poisson intensity, λ, 0.25.

		Based on COI		Qualified IPO Restrictions	
Names	PMV	FV	Δ_V	FV	Δ_V
Uber	68.0	60.6	12%	44.8	52%
Airbnb	30.0	26.1	15%	18.2	65%
Palantir	20.5	17.8	15%	13.0	58%
Snap	20.0	19.0	5%	19.0	5%
WeWork	16.0	13.5	18%	9.8	63%
Pinterest	11.4	9.4	21%	6.9	64%
SpaceX	10.5	6.4	64%	6.2	69%
Theranos	10.5	8.0	31%	3.9	166%
Dropbox	10.4	8.6	21%	5.6	84%
Twitter	9.3	7.6	21%	5.1	81%
Average			22%		71%

Table 11: SpaceX Financing Rounds At Time of Series D

This table summarizes the financing SpaceX received up to and including its Series D round. Round dates and (post-money) valuations are from CBInsights, public disclosures, and Dow Jones VentureSource. Investment amounts, share numbers, and payouts are from publicly available Certificates of Incorporation. Minimum M&A payout is set equal to the liquidation payout. The minimum payout for the "sale/failure' column is set equal to the amount each share is entitled to, prior to common shares getting anything, in the event of a sale or a failure. In the IPO case, the minimum payout is set equal to 0 unless there are terms that either 1) provide a minimum return to investors, in which case it is set to that return or 2) allow investors to avoid converting in IPOs below a certain value, in which case it is set equal to the lesser of the IPO value that allows them to avoid conversion and the 'sale/failure' minimum payout. PM stands for post-money, and OIP is for original issue price,

Series	Date	PMV ($m)	Investment ($m)	Shares (m)	OIP	Minimum M&A Payout ($)
D	Aug 2008	382	29	8	3.88	7.76
C	Mar 2007	9	32	11	3.00	3.00
B	Mar 2005	190	11	6	2.00	2.00
A	2002–2005	85	61	61	1.00	1.00
Common				9		-
Unissued Stock Options				5		