Squaring Venture Capital Valuations with Reality*

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Abstract

We develop a valuation model for venture capital-backed companies and apply it to 135 U.S. unicorns – private companies with reported valuations above $1 billion. We value unicorns using financial terms from legal filings and find reported unicorn post-money valuation average 50% above fair value, with 15 being more than 100% above. Reported valuations assume all shares are as valuable as the most recently issued preferred shares. We calculate values for each share class, which yields lower valuations because most unicorns gave recent investors major protections such as a IPO return guarantees (14%), vetoes over down-IPOs (24%), or seniority to all other investors (32%). Common shares lack all such protections and are 58% overvalued. After adjusting for these valuation-inflating terms, almost one-half (65 out of 135) of unicorns lose their unicorn status.

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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 have gone 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 and have grown to enormous size without a public offering. 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," which denotes a VC-backed company with a reported valuation above $1 billion. Once thought to be rare, as of mid-2017, there are more than 100 unicorns in the U.S. and another 100 in other countries.[1]

With the reported valuation of these unicorns totalling over $700 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 Investments 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 tenfold 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.[2]

Despite the growing importance and accessibility of VC investments, the valuation of these companies has remained a black box. This is due in part to the difficulty of valuing high-growth companies. But to a large extent, it is due to the extreme complexity of these 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

[1] See, e.g. https://www.cbinsights.com/research-unicorn-companies. Accessed August 22, 2017.

[2] 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.

unicorn in our sample has eight share classes, where different classes can be owned by the founders, employees, VC funds, mutual funds, sovereign wealth funds, strategic investors, and others.[3]

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 Square Inc.'s October 2014 Series E financing round where the company raised $150 million by issuing 9.7 million Series E Preferred Shares for $15.46 per share to a variety of investors. These shares had the same payoff as common shares if the company did well, but additional protections if the company did poorly. The Series E investors were promised at least $15.46 per share in a liquidation or acquisition and at least $18.56 per share in an IPO, with both of those claims senior to all other shareholders. These Series E 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-diluted number of common shares (with convertible preferred shares and both issued and unissued stock options counted based on the number of common shares they

[3]Although such equity issuance is uncommon for mature firms, Fulghieri, Garcia, and Hackbarth (2013) show equity financing is natural for young, risky firms with significant investment needs.

convert into). After its Series E round financing, Square had 253 million common shares and options and 135 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 for Square:

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

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. The \$6 billion assessment of Square was reported as its fair valuation by the financial media, from *The Wall Street Journal* to *Fortune* to *Forbes* to *Bloomberg* to the *Economist*.[4]

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 price of Square's November 2015 IPO was \$9 per share, 42% below the Series E price. 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 entire company.

[4]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 modeling framework to derive the fair value of VC-backed companies and of each class of share they issue, taking into account the intricacies of contractual cash flow terms. Our model shows that Square's fair valuation after the Square's Series E 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%. Square is not a unique case: we apply our model to a sample of 135 U.S. unicorns and find post-money valuations overstate company values in all cases, with the degree of overvaluation ranging from 5% to a staggering 250%. To do so, we extract contractual terms of unicorns from Certificates of Incorporation and develop a methodology to reconstruct their capital structure. We find that IPO guarantees and other previously unexplored terms, such as automatic conversion vetoes, are both common and quantitatively important.

Our results show that it is inappropriate to equate post-money valuations and fair values. However, even sophisticated financial intermediaries make this error. 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' 2015 Series D-1 and Common Shares at the same price.[5] We find the D-1 Preferred Shares were worth 35% 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, in 2015 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 many VC funds follow the same practice and mark their holdings up to the most recent round. Even within the VC industry, many people appear to 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:

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

> 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 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.*

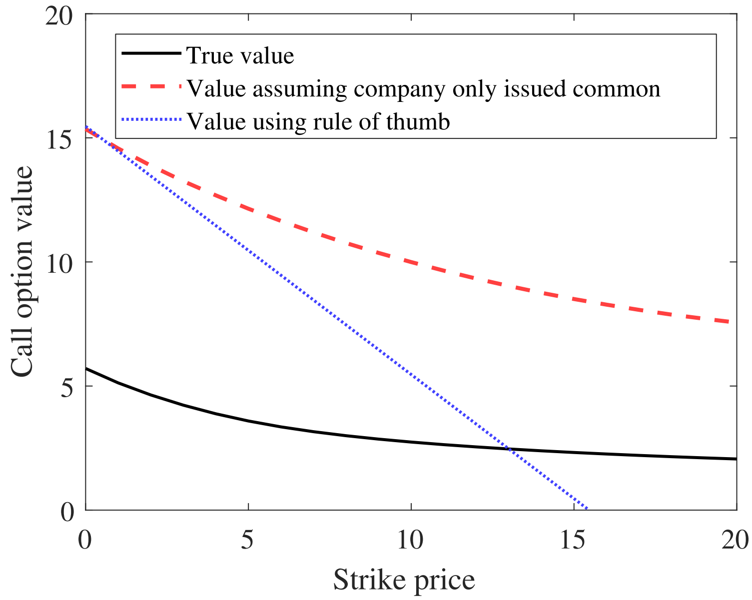
Although EquityZen provides nine pages of analysis on Wish, the fact that the valuation is set using preferred stock and that investors are buying common stock is not clearly mentioned. The preferred stock that Digital Sky Technologies purchased here has strong preferences, including the right to its money back in exits other than IPO and a right to keep its preferred liquidation preference in an IPO, unless that IPO provides a 150% return. 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. Many employees use post-money valuation as a reference when valuing their common stock or option grants, which can lead them to dramatically overestimate their wealth. For example, many of the stock options Square issued around the time of its October 2014 Series E funding round had a strike price of $9.11.[6] Figure 1 shows the value of these options as a function of the strike price under three possible valuation scenarios. The first scenario is the fair value produced by our model, which says options with a strike price of $9.11 are worth $2.85. The second scenario ignores the capital structure complications and calculates the fair value of the option under the assumption that one common share is worth $15.46. Being unaware of Square's complex capital structure would lead one to estimate the value of those options as $10.32, a 262% overvaluation. The third scenario shows the value under a 'rule of thumb' approximation used by many employees, which estimates the value of a stock option as the difference between the most recent round's value and the option's strike price. That naïve approach values the stock options at $6.34, for a 123% overvaluation.

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

Figure 1: Value of Options on Square's Common Stock

This figure reports the value of options on Square's common stock, as of the company's October 2014 Series E round. The solid line shows the fair value of an option with varying strike price. The dashed line shows the value of that option if Square had only common shares. The dotted line shows the value of that option using a rule of thumb that sets option value equal to the difference between the most recent share price and the option's strike price. Square's capital structure at each round is reconstructed from its Certificates of Incorporation using the method in Section 3.3 and its fair values are calculated using the model and parameters in Section 2.



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 its post-money valuation by 36% from the previous round by promising Series D Preferred Shareholders twice their investment back. Our model shows that SpaceX's reported valuation was four times its fair value and despite the reported valuation increasing by 36%, its fair value had fallen by 67%. These generous terms are not necessarily evidence of active post-money 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.

In this paper, we develop a contingent-claim valuation framework for valuing of VC-backed companies. Beginning with Black and Scholes (1973) and Merton (1974), researchers have used share prices to value warrants, options, bonds, and other contracts. We reverse this 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 (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 of VC-backed companies often rely on similar techniques. However, the goal of these valuations is tax compliance rather than strategic and their results are not used by decision makers – mutual funds and VC funds do not mark their shares to the 409A price. Because these valuations are not a strategic tool, accuracy is a low priority and 409A valuations commonly use assumptions that decrease tax by reducing values.[7] The 409A valuation provider eShares finds that common equity is overvalued by approximately 186% for the median Series C company – far above our median overvaluation of 37%.[8]

We also develop methodology to reconstruct capital structure of unicorns based on contractual terms from Certificates of Incorporation. Our analysis, based on these extracted contractual terms, shows that previously ignored terms such as IPO ratchets and automatic conversion vetoes, are extremely important.

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 VC 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), Metrick and Yasuda (2010a), and Robinson and Sensoy (2013) look at the role and impact of VC compensation provisions. Barber and Yasuda (2017), Brown, Gredil, and Kaplan (2017), and Chakraborty and Ewens (2017) look at how venture capitalists report the value of their stakes to

[7] For example, Square used volatilities of 0.44–0.47 to value its common stock, as listed in its S-1 filing retrieved February 28, 2017 from http://www.nasdaq.com/markets/ipos/filing.ashx?filingid=10529767. These low volatility number produces a low valuation.

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

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. Cong, Howell, and Zhang (2017), Gao, Ritter, and Zhu (2013), Ritter (2015), and Ritter and Welch (2002) study various aspects of the IPO market, including its impact on the VC industry. Metrick and Yasuda (2010b) provide a textbook treatment of the venture capital industry. In particular, they discuss the nature of post-money valuation and its difference from fair value and describe the contingent claims approach to post-money valuation. 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 our findings. Section 6 contains concluding remarks.

2 Valuation Model of a VC-Backed Company

In this section, we develop a valuation model of a VC-backed company and apply it to the 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 discuss our model implementation in Section 2.3 and the parameters we use in Section 2.4.

2.1 Contingent Claims Model

We use the price of a VC-style financing round to find the fair value of that company at the time of that round. Consider a company that raises a financing round of amount I at time 0. The company will exit at value $X(T)$ at some time T in an IPO, an M&A, or a liquidation. All shareholders are paid out at exit, with the investor's payoff being a function of the exit amount, $f(X(T))$.[9] The form of the payout function f depends on the contractual features of the securities used in that round, as well as all other rounds. As investors in VC-backed companies rarely receive intermediate payoffs, it suffices to consider this terminal payout.

We use $V(t)$ to denote the time t value of the investors' discounted payoff and $X(t)$ to denote the time t value of the discounted total exit. In order to discount these cash flows, 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 volatility σ that grows at the risk free rate r_f and 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 (2010a) used the same set of assumptions to model VC investment cash flows. In Section 2.4, we show that both sets of assumptions are reasonable for VC-style investments.

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

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

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 round.

Investments in VC-backed companies are traditionally priced in terms of so-called post-money valuations. To illustrate how this way of pricing works, suppose that investment I occurs at post-money valuation P, using the most standard form of VC security, convertible preferred equity. This security gives

[9] In reality, many investors receive payouts later than T due to regulatory provisions, such as IPO lock ups, or negotiated agreements, such as incentives in M&As. For our purpose, we discount all of those payouts to time T.

investors the option to either convert their preferred shares into common shares or leave their preferred shares unconverted for a senior claim. If this round's investors convert, they are entitled to own I/P fraction of the company's common shares. If they do not convert, they retain a claim of I that is senior to common shares. In other words, the investors' payoff is the greater of the converted and unconverted payoffs:

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

More generically, if there is more than one class of claimants that could convert into common shares, the ownership fractions determined by post-money valuations assume all relevant claims are converted to common shares at exit. The total number of common shares in this scenario is known in the industry as the fully-diluted basis. If some claimants do not convert, this round's investors are entitled to a higher ownership fraction of common shares than I/P.

In addition to this optional conversion, most convertible preferred equity shares are subject to automatic conversion (also known as mandatory conversion) clauses that force these shares to convert into common shares 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 a qualified IPO, preferred shares must convert into common shares even if it reduces their payout (e.g., the IPO share price is below the share price at which they invested).

We model automatic conversion terms by writing the exit payoff, $f\left(X(T)\right)$, as the sum of the payoff in an IPO, $f^{IPO}\left(X(T)\right)$, and the payoff in M&A or liquidations that cannot trigger automatic conversion, $f^{M\&A}\left(X(T)\right)$, weighted by the probability of each outcome conditional on the exit value, $p^{IPO}\left(X(T)\right)$ and $1 - p^{IPO}\left(X(T)\right)$:

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

The payoff in an M&A exit is just Equation (4). If an IPO triggers automatic conversion, investors get their converted payoff:

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

If an IPO does not trigger automatic conversion, investors get the same choice between the conversion and liquidation that they would get in an M&A or liquidation:

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

According to industry practitioners, it might be difficult for a company to go public unless all of the preferred shares convert. We therefore assume that if any investors 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, multiple financing rounds do not change our results if they do not make current investors better off or worse off. Equivalently, in our model we need future financings to occur at a fair price and to not redistribute wealth between the existing investors. In Section 4.3, we relax that assumption.

2.2 Modeling Contract Terms

In this section, we introduce the key cash flow terms used in the financings of VC-backed companies and how those 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 (Kaplan and Strömberg 2003). Our model can be used to price all of these modifications by adjusting the payoff function f. Although this section discusses only the most important contractual terms, 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. As a baseline case, take a prototypical unicorn that is raising \$100 million of new VC investment at \$1 per share 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 from at a post-money valuation of \$450 million using the preferred shares with the same terms and pari passu seniority with the newly issued shares. Using subscripts to denote the different rounds, $P_1 = 450$, $P_2 = 1,000$, $I_1 = 50$, and $I_2 = 100$ (all values in millions). After the current round, if all shares convert, the new investor owns 10% of the total shares, the old investor owns 10%, and the current common shareholders own the remaining 80%. Putting this together, the payout to the new investor in an IPO is the converted payoff in Equation (6) and in an M&A exit or liquidation is as follows:

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

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 the company's overvaluation, Δ_V, as the ratio of the post-money valuation to the fair value implied. We define the common shares' overvaluation, Δ_C, as the ratio of the most recent round's share price to the fair value of a common share. The results show a fair value of \$771 million correctly prices a VC round with a post-money valuation of \$1 billion. The post-money valuation exaggerates the company's value by 30% and the value of common shares by 28%.

The following paragraphs introduce the most important cash flow rights granted to unicorn investors. The Online Appendix contains examples of unicorns using each of these terms.

Liquidation preference. Liquidation preference terms give investors a guaranteed payout in exits that do not trigger automatic conversion, such as liquidations or M&A exits. Our baseline case has investors receiving one times their money back (referred to as a 1X liquidation preference). This is the most common case, but other multiples are possible. For example, Uber's Series C-2 Preferred Shares had a 1.25X liquidation preference and AppNexus's Series D Preferred Shares had a 2X liquidation preference. If the new investor is guaranteed a return of L times her initial investment (an LX preference) and that claim is pari passu with the old investor, the new investor's payout in all exits not triggering automatic conversion is

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

Higher liquidation multiples increase the value of preferred shares and thus 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 VC financing rounds include an option pool – unissued shares that are held aside for future option-based employee compensation. The post-money valuation approach incorrectly includes these unissued options in the valuation. To see this, note that plans for future dilutive share issuances do not increase the current fair value of a company. Clearly, a company cannot arbitrarily increase its value by authorizing (and not issuing) a large number of shares. Beyond governance concerns, the timing of the authorization of unissued shares does not impact cash flows, and only the timing of their actual issuance matters. Rather than authorizing the unissued shares at the time of the financing round, the company could authorize the shares immediately afterward 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%. The presence of option pools means that for companies where preferred shares have few additional rights, the round price may overvalue common stock by less than the post-money valuation overvalues the company.

Seniority. Many unicorns make their most recent investors senior to all other shareholders, so that their liquidation preference must be satisfied before other investors receive anything. For example, Intarcia 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:

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

This is extremely uncommon in practice, but even in this case there is still significant overvaluation because even junior preferred equity is senior to common equity.

Participation. Participation terms gives investors that do not convert their shares 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 investors 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:

$$f_2^{M\&A}(X) = \begin{cases} \frac{I_2}{I_1+I_2}X & \text{in liquidation} \\ \max\left\{\min\left\{CI_2, I_2 + (X - I_2) \times \frac{I_2}{P_2}\right\}, \frac{I_2}{P_2}X\right\} & \text{if Series A converts} \\ \max\left\{\min\left\{CI_2, I_2 + \frac{(X-I_2-I_1)\times I_2/P_2}{1-I_1/P_1\times(1-I_2/P_2)}\right\}, \frac{I_2/P_2}{1-I_1/P_1\times(1-I_2/P_2)}X\right\} & \text{otherwise} \end{cases}, \tag{12}$$

where liquidation takes place if $X \leq I_1 + I_2$ and Series A converts if

$$X > \max\left\{\min\left\{\frac{P_1 + I_2\left(1 - I_2/P_2\right)}{1 - I_2/P_2}, P_1 + I_2 C\right\}, \frac{P_1}{1 - I_2/P_2}\right\}. \tag{13}$$

Participation increases the value of preferred shares relative to common shares, 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 in this example: 50% overvaluation persists even with the common 2.5X cap. The effect is small because we consider a highly valued company for whom successful exits are likely to be high-value IPOs, in which convertible preferred equity is automatically converted. For a smaller company, caps can have a large impact on overvaluation.

IPO Ratchet. IPO ratchet terms give some investors extra shares in IPOs where the share prices are below a pre-agreed threshold. Pivotal, Oscar, and many other unicorns gave their most recent investors an IPO ratchet that ensures these investors always at least break even in IPOs. Some contracts go further: investors holding Series E Preferred Shares in Square were guaranteed at least a 20% return, referred to as a 1.2X IPO ratchet. Guaranteeing the new investor a return of R times her initial investment in an IPO changes her IPO payout to

$$f_2^{IPO}(X) = \max\left\{\min\left\{X, R \times I_2\right\}, X \times \frac{I_2}{P_2}\right\}. \quad (14)$$

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

Automatic Conversion Exemption. Automatic conversion provisions force preferred shareholders to convert their shares in an IPO, even when converting reduces their payoff. 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 shares. The Honest Company 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 investors 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

$$f_2^{IPO}(X) = \begin{cases} f_2^{M\&A}(X) & \text{if } f_2^{M\&A}(X) > X \times \frac{I_2}{P_2} \\ X \times \frac{I_2}{P_2} & \text{otherwise} \end{cases} . \tag{15}$$

Table 1 shows that overvaluation of 55% results if the new investor is exempted from converting in all down-exits. Even exemptions that only bind on low IPOs, such as those below 50-75% of the PMV, 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 investor 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 new investor 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 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 \$30m follow up Series E round in 2015. Square's Series E Shares were given a 1X liquidation multiple with seniority and a 1.2X IPO ratchet. These special protections make Series E Shares more valuable than the common shares, which mean the post-money valuation exaggerated Square's value. As reported in *The*

Wall Street Journal, Square's post-money valuation after its October 2014 round was \$6 billion:

$$\$6 \text{ billion} = \underbrace{\$15.46}_{\substack{\text{Series E}\\ \text{Issue Price}}} \times \Big(\underbrace{233 \text{ million}}_{\substack{\text{Common Shares}\\ \text{and Options}}} + \underbrace{19 \text{ million}}_{\substack{\text{Unissued}\\ \text{Options}}} + \underbrace{47 \text{ million}}_{\substack{\text{Series A}\\ \text{Preferred Shares}}} + \underbrace{14 \text{ million}}_{\substack{\text{Series B-1}\\ \text{Preferred Shares}}} + \cdots + \underbrace{10 \text{ million}}_{\substack{\text{Series E}\\ \text{Preferred Shares}}} \Big). \tag{16}$$

We use our model to price each of Square's shares at the time of its October 2014 round. The results in Table 2 show that Square had a fair value of \$2.2b at the time of its \$6b Series E round. Square's Series E shares were worth three times as much as its Common shares and its Series A and B Preferred shares. Square's unissued stock options were worth nothing because they were 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%. Square issued another \$30m of Series E securities in 2015, which pushed its post-money valuation up to \$6.03b and its fair value up to \$2.3 billion.

In November 2015, Square went public at \$9 per share and pre-IPO value of \$2.66 billion, substantially less than its \$6b post-money valuation in October 2014. The Series E preferred shareholders were given \$93 million worth of extra shares because of their IPO ratchet clause. This reinforces the idea that these shares were much more valuable than common shares and that Square was in fact highly overvalued. As we show in Section 5, high overvaluation predicts unsuccessful exits.

2.3 Model Implementation

Beyond the simplest contracts, our model does not have closed-form expressions for fair values. We value securities by integrating their discounted payoffs across all possible exit values X and times T. This integration is straight-forward based on the probability distributions in Section 2.4. What is challenging is calculating the payoffs themselves.

Calculating payoffs is not always straightforward, because unicorns typically have many share classes. We start by determining which securities can choose not to convert. If the exit is a qualified IPO, then securities must convert unless their class has an automatic conversion veto. Otherwise, every preferred shareholder has this choice.

As the first step in the payoff calculation, we assume that all shareholders convert their shares. In this case, the 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 process converges to a Nash equilibrium.

Each class of shareholders acts strategically and exercises its conversion option, votes, and uses vetoes 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 share class. 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 the liquidation preference of each class of shares in that seniority class which chooses not to convert. After liquidation payouts, the surplus cash is distributed pro-rata 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 the 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. Further robustness checks are contained in Section 4.3 and charts in the Online Appendix illustrate how variation in these parameters impacts overvaluation.

Volatility σ. We use 0.9 as our baseline volatility parameter, a value also used by Metrick and Yasuda (2010a). Cochrane (2005) estimates the annualized volatility of VC investment returns at 0.89. 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. For example, overvaluation in our baseline case varies between 26% and 31% for volatilities between 0.5 and 1.3. Extremely high and extremely low volatilities lead to lower estimates of overvaluation. Section 4.3 reports robustness tests with respect to volatility for our empirical sample.

A potential concern is that the growth of these companies is 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.

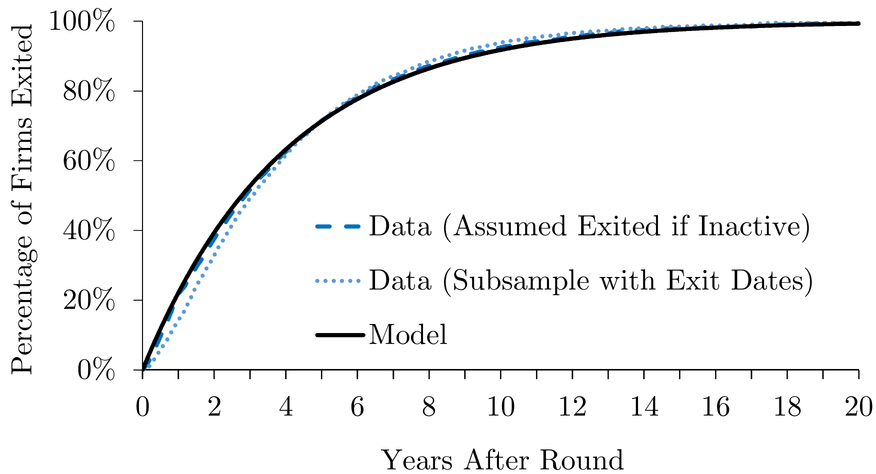
Exit Rate λ. To estimate the rate, λ, at which unicorns exit, we use data on exits from VentureSource. While VentureSource has relatively complete data on the dates of funding rounds, IPOs, and M&As, the dates of failures are generally not reported and companies remain "active" long after their demise.

We look at all companies that exited between July 1, 1992 and July, 1 2015. As we are interested in unicorns, we consider only companies with at least four rounds of VC financing. We have data on 10,523 companies and 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 the time between the sixth round and an

[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 2: Time to Exit Dispersion in VentureSource and Model

This figure reports the percentage of firms that have exited at different times after a financing round. Our model (solid line) has firms exit at an exponential rate of $\lambda = 0.25$. This is compare to the time to exit for fourth or later VC financing 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.



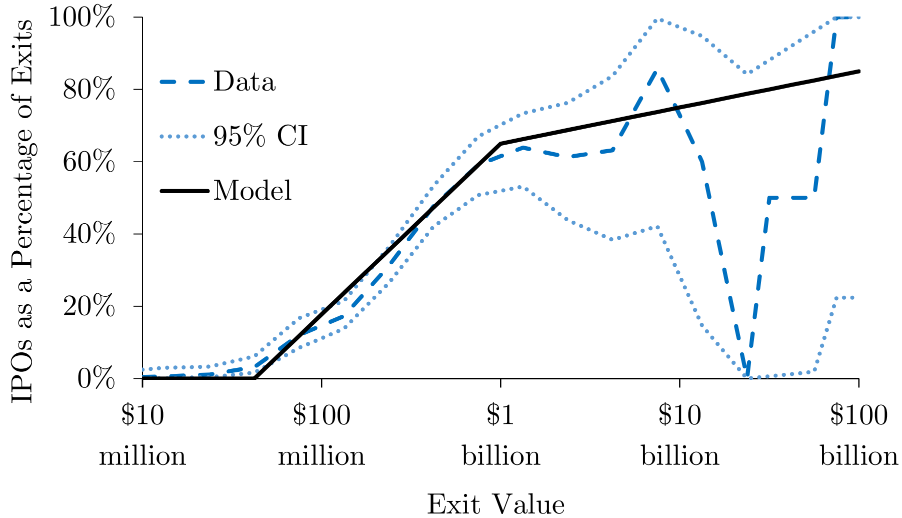
exit is 3.5 years. As the baseline parameter, we take the value of 0.25 for λ, which results in an average expected exit time of 4 years. Metrick and Yasuda (2010a) use a similar exponential distribution assumption, but with a rate of 0.2 for their sample including early-stage VC-backed companies. As unicorns are larger, more mature, and closer to exit, we use a higher rate of 0.25 to better match the data.

In Figure 2, 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. We also plot the empirical distribution of all companies, including those without reported exits, by assuming that those with no activity for three years have failed. We assume these failures occurred at a uniform rate between zero and one year after their final financing round. 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

Figure 3: Probability of an IPO Conditional on Exit in VentureSource and Model

In Figure 3, we plot the probability of an IPO exit conditional on exit value. Our model (solid line) is compared to VentureSource data from 2005 to mid-2015 on the exits of VC-backed companies. We group 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).



3, 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 3 show that M&A exits are frequent even among the largest companies. In fact, the two of the largest recent exits are WhatsApp's $22 billion sale in 2014 and Stemcentrx's $10.2 billion sale in 2016. Based on these data, we calibrate the following piecewise linear function for the probability of an IPO exit for a given exit value:

$$p^{IPO}(X) = \begin{cases} 0 & \text{for } X \leq \$32m \\ 0.65 \times \frac{\log(X)-\log(\$32m)}{\log(\$1b)-\log(\$32m)} & \text{for } \$32m \leq X \leq \$1b \\ 0.65 + 0.2 \times \frac{\log(X)-\log(\$1b)}{\log(\$100b)-\log(\$1b)} & \text{for } \$1b \leq X \leq \$100b \\ 1 & \text{for } \$100b \leq X \end{cases} \quad (17)$$

[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.

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 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 shareholders 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.

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 the risk-free rate rises, and therefore our choice of 0.025 is relatively conservative.

3 Data

In this section, we construct a sample of U.S. unicorns and gather their financial structure data. We first discuss the commercial data sets and legal filings used in our analysis (Section 3.1). We then 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 Legal Filings and Data Sets

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 provides the contractual relations between various classes of shareholders. 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 VCExperts, which has a substantial number of scanned COIs from Delaware and other states. Chernenko, Lerner, and Zeng (2017) use this data source to examine the control and cash flow rights given to mutual fund investors in unicorns.

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. Therefore, we have multiple COIs for most unicorns in our sample, allowing us to trace out the paths of their fund raising. For example, we have 20 COIs for Uber.

COIs are complicated legal documents and there is a large variety of ways different terms can be described, often in a very convoluted fashion (e.g., forced conversion is called either automatic or mandatory in different COIs). We employed three lawyers and three law school students to extract and code these data. All COIs were analyzed by at least one lawyer (two in most cases and three in more complicated cases) and both of the coauthors.

We supplement this information with basic data such as amount raised in each round, post-money valuation, and company founding date, which we gather from VentureSource, Thomson One, CB Insights, and PitchBook. We utilize multiple data sources to minimize the impact of data errors.[12] In a number of cases, we consulted media reports and the COIs themselves 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 vetoes and ratchets and have mixed quality on other terms. Consequently, we hand-collect contractual data from the COIs.

3.2 Sample of Unicorns

We define a unicorn as a company that raised money from a VC and had a post-money valuation over $1 billion in at least one of its private rounds of financing. This includes companies valued at over $1 billion in the past whose valuation subsequently decreased and excludes companies whose only valuation over $1 billion was the value at exit (either the IPO valuation or the M&A value). To focus

[12] There are numerous inconsistencies between these datasets. 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 a valuation of $14 billion, Thomson One reports 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.

on fast-growing companies, we restrict our analysis to companies founded after 1994 with a VC round after 2004. We further limit ourselves to U.S. companies, as we are unable to gather contract data for foreign companies.

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 and Thomson One.[13] This analysis yielded more than 400 companies. For each company, we gathered its financing history across databases and confirmed that had a VC round with a post-money valuation over $1 billion after 2004, was based in the U.S, and was founded after 1994. 156 unicorns met all of these criteria. The full list is given in the Online Appendix.

Table 3 provides the summary statistics on the unicorns meeting our criteria. Of those 156 unicorns, we exclude 14 companies where we are unable to find the COI for their latest VC round. We exclude another 7 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 share price, which prevents us from calculating the company's value. Another example is Mozido's December 2014 COI, which references a Put Agreement that was not filed with Delaware and thus not visible.

Our main sample, on which all of the subsequent analysis is based, consists of 135 unicorns. The 135 companies in our main sample and the 21 unicorns we excluded 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 $250 million at a valuation of about $3.5 billion post-money valuation in 2015. Of the 135 companies in our sample, 91 are still private as of August 1, 2017, 12 were acquired, 30 went public, and 2 failed (Solyndra and Better Place). These proportions are broadly similar to the 21 excluded unicorns.

[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.

3.3 Financial Structure and Cash Flow Terms

COIs list the main contractual relations between classes of shareholders. First, 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 cash flow terms highlighted in Section 2.2 and all other material terms. Many COI use intricate and non-standard payoff structures. We calculate payoffs as written and have consulted with several lawyers, who are experts on VC and contract law, on the interpretation of unclear cases.

Second, COIs report the number of shares of each type that the company is authorized to issue. Importantly, not all of these "authorized" shares are issued. The authorized number is the maximum number of shares the company can issue in each class and not all authorized shares are issued. 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 per share. The price 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:

$$9.7 \text{ million} = \frac{\$150 \text{ million}}{\$15.46}. \tag{18}$$

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 COIs subsequent to a financing round generally reduce the authorized preferred share number to match the number actually issued.

[14]This may lead us to underestimate overvaluation, as shown in Section 4.3, due to the investment amount effects described in Section 2.2.

Our next step is to estimate the number of common shares. COIs give the number of authorized common shares, but this is generally larger than the number of shares actually issued. We estimate the number of common shares using the post-money valuation. We first calculate the number of fully diluted shares as the post-money valuation divided by the share price (the reverse of the post-money 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 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. We implicitly assume that issued stock options and warrants have the same value as common stock, an assumption that will decrease the overvaluation estimates (this assumption is relaxed in Section 4.3).

4 Unicorns are Overvalued

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

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

4.1 Special Contract Terms

Section 2.2 shows how IPO ratchets and other contractual terms inflate valuations. Table 4 reports the frequency of these terms in our sample. These contractual terms are the result of negotiations between managers, existing shareholders, and the new investors. The diversity in terms we observe gives further credence to the importance of contracting in VC-backed companies, as discussed by Kaplan and Strömberg (2003), who examine a sample of very early-stage companies.

Our unicorns have many rounds of financing and we start by analyzing the contractual terms given to the latest, or new, investors. Table 4 shows that the new investors are on average senior to more than half of all the outstanding shares. New preferred shares are always senior to all common shares.[16] However, in 66 out of 135 unicorns, new investors are also senior to some existing preferred shareholders. Moreover, in 43 unicorns, new investors are senior to all the existing shareholders. These complicated seniority structures are consistent with work by Hackbarth and Mauer (2011) who show this is an optimal choice for high-risk firms.

The most recent investors have greater than 1X liquidation preferences in 8 unicorns and participation in 17. IPO ratchets are given to the most recent investors in 19 unicorns, typically with a 1X ratchet.[17]

Enforceable automatic conversion exemptions were given out by 94 out of 135 unicorns.[18] Among these 94 unicorns, the average exemption covers all IPOs with exit value below 46% of the post-money valuation and the median exemption covers IPOs below 24% of the post-money valuation. In 92, automatic conversion is not triggered by IPOs with proceeds below some minimum level. In 37, this exemption takes the form of a valuation requirement or a per-share payout, with the median case requiring a return of 1X for the latest round for automatic conversion to be triggered. 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

[16] Snap is an outlier here as in several of its rounds it issued preferred stock with no liquidation multiple, which is neither senior nor junior to common.

[17] 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 time (after 4 years) for these statistics.

[18] As discussed in Section 2.2, we exclude automatic conversion exemptions that will be overridden by a shareholder vote.

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.

A new investor has a major protection if they have at least one of the following 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 75 unicorns, more than half of our sample, the most recent investors had one or more major protections.

We also analyze whether any shareholders, including existing shareholders, had special rights. 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 eight unicorns feature a liquidation multiple above 1X in the most recent round, 21 feature these high liquidation multiples for at least one investor. Only 17 gave their most recent investors participation, but 26 gave at least one of their investors participation. This variation can stem both from time variation in contractual terms and changes in a company's fortunes. Overall, we find that 93, or two-thirds of the sample, provide a major protection to at least one investor.

Table 5 shows how these terms impact the returns to the most recent class of investors in exits that are below the post-money valuation at which they invested. In M&A exits, the most recent investors are very well protected. Even if the 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 investors 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 get a guaranteed payout; if they do not, they undergo an unfavorable conversion. These protections mean that the most recent investors recoup 46% of their investment in a down-IPO 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 investors are still much less than the share price decline.

Holding exit value constant, the most recent investors do better in M&As than in 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 lose 45% of their investment in an

IPO. Recoveries are higher in M&A exits because almost every company offers preferred shareholders a liquidation multiple of at least 1. This further supports the importance of automatic conversion exemption clauses and contractual features that make it easier or more difficult to override those clauses.

As the total payout is fixed, down exits where preferred recover their original investment must be down exits where common suffers losses. In an M&A exit 75% below the most recent round's post-money valuation for the median unicorn, the most recent preferred shareholders receive their investment back while each common share receives 91% less than that. This pattern repeats across down M&A exits, with common suffering large losses. In down IPOs, automatic conversion terms mean the per-share payouts are often equal.

4.2 All Unicorns are Overvalued

Table 6 provides a summary of the results of our valuation model for the 135 unicorns in our sample on the day of their latest unicorn financing round. The average (median) post-money valuation is $3.3 billion ($1.5 billion), while the corresponding average (median) fair value is only $2.6 billion ($1.0 billion). This results in a 50% (37%) overvaluation for the average (median) unicorn. Common shares are even more overvalued, with an average (median) overvaluation of 58% (41%).

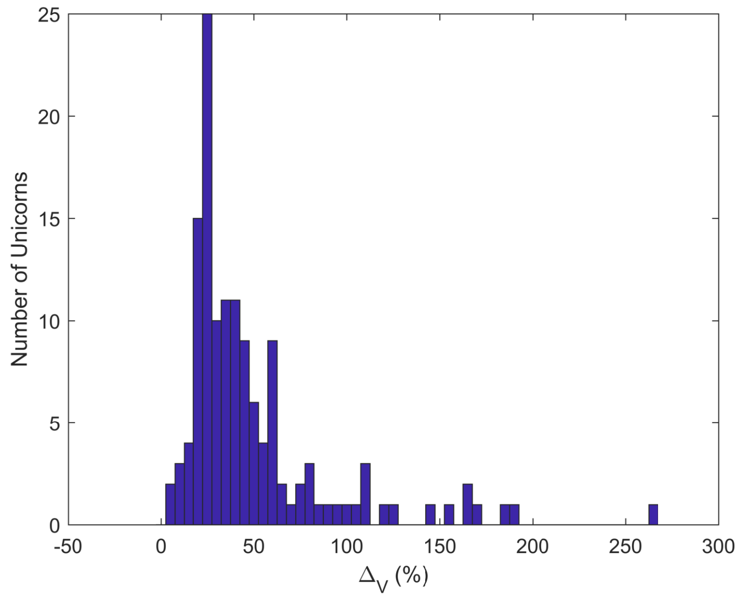
Table 7 shows the model results for each unicorn. We find that 65 of the 135 unicorns lose their unicorn status when their values are expressed on a fair value basis. As shown in this table and in Figure 4, there is a large distribution in overvaluation, with many unicorns only slightly overvalued and 15 overvalued by more than 100%.

Overvaluation arises because the most recently issued preferred shares have strong cash flow rights. The last columns of Table 7 list the terms that impact each unicorn. Companies where the most recent preferred shareholders have stronger rights are overvalued the most.

For example, in Aug 2014, JustFab offered Series E investors an IPO ratchet, participation, and seniority, which resulted in an overvaluation of 111%, 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%,

Figure 4: Distribution of Unicorn Overvaluation

This figure shows the distribution of overvaluation of the total value, Δ_V, for the unicorns in our main sample. Δ_V is the percentage that the post-money valuation overstates the company's fair value. Unicorn capital structures are reconstructed from Certificates of Incorporation using the method in Section 3.3 and fair values are calculated using the model in Section 2.



resulting in an overvaluation of 126%. Better Place offered investors cumulative dividends, the ability to obstruct down-IPOs, and seniority, resulting in a 120% overvaluation and a 180% overvaluation of common in its November 2011 Series C round (prior to its May 2013 bankruptcy).

Terms that even more blatantly alter the valuation are possible. JetSmarter's Dec 2016 Series C round offered the new investors 25% more shares when they converted, unless the company managed to double its valuation within two years. This effectively increases the valuation by 25%. Jawbone offered its Series 9 investors a clause with similar effect.

At the other end of the spectrum, the most recent investors in Uber have few extra rights and are subject to automatic conversion in most IPOs and so Uber's 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 situation arises because Snap issued preferred shares with no liquidation preference in its recent financing rounds, giving the VC investors the same payout as common equity holders. Snap is the only company we found that issued what is effectively common equity in this manner.

Taken together, these results indicate that post-money valuations are substantially above fair values for many unicorns because of the preferential contractual terms they gave their most recent investors.

4.3 Robustness

Our overvaluation results persist under many specifications. In this section, we examine 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 8 shows how overvaluation changes in the different scenarios we consider. Throughout this section, we report the impact of these assumptions on the median overvaluation of our 135 unicorns, which is 37% under our main parameters.

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. In this section, we test how changing these assumptions impacts valuation.

Valuation Errors. Because companies authorize more shares than they have actually issue, 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 releases 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 overvaluations. If post-money valuations is inflated, the fair values will be inflated by roughly same amount and as shown in Table 8, overvaluations will change only slightly. For example, if the true post-money valuations were all 20% above our recorded numbers, overvaluation increase slightly to 39%. 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 on 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 shares and fewer low-valued common shares. As a robustness check, we assume the entire round, as authorized in the COI, was issued, rather than the amount that was reported issued. This leaves median overvaluation unchanged.

Unissued Options. We assume that unicorns include a 5% pool of unissued stock options in their post-money valuations. This option pool raises overvaluation as unissued options are not included in the fair value. Data from J. Thelander Consulting suggest that the median option pool size is 16% for firms with $90 million or more in financing.[19] The S-1 data of now-public unicorns is consistent with unicorns actively issuing options. Square issued 38 million options implying at least a 10% option pool. As we cannot be sure these options came from an option pool, we use a low number of 5% to be conservative. If we assume there is no option pool, median overvaluation at the company level falls by 7% to 30%. Conversely, assuming a 10% option pool increases overvaluation to 44%.

Issued Options. 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 of the most recent round's price. In this scenario, overvaluation increases to 39%.

Debt. We assume that the companies in our sample do not issue significant amounts of debt. In practice, VC-backed companies do not issue much debt and the debt that is issued generally has significant option-like components. This follows naturally from our volatility assumption, which effectively shuts unicorns out of the traditional 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

[19] See http://pitchbook.com/news/articles/how-big-should-an-employee-option-pool-be. Accessed August 15, 2017.

reduce leverage further: a repayment at exit equal to 14% of present fair value gives us 10% leverage and reduces median overvaluation to 25%.

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 shares are converted into common shares; thereby losing their special rights. Even though 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 shareholders lose their rights 25% of the time, clearly an extreme assumption) overvaluation is reduced to 28%. Although this is a substantial fall in overvaluation, our assumption here is very likely conservative.

Hold up in IPOs. We have assumed that preferred shareholders who are not automatically converted can hold up an IPO and that they choose to do so. Alternatively, we can assume they do not hold up an IPO, even when it destroys value for them. This reduces the payoff to the most recent investor; thereby reducing overvaluation median overvaluation to 27%. If we assume that these shareholders can hold up the IPO 50% of the time, median overvaluation is 32%.

4.3.2 Model Parameter Assumptions

Section 2.4 shows how varying parameters impact the results for our simple unicorn example. This section repeats that analysis for the main sample of 116 unicorns and finds similar results.

Volatility. Volatility has a non-monotonic relation with overvaluation. It increases the likelihood of liquidation preferences being claimed, yet reduces the value in the scenarios when they are claimed. Increasing volatility to 1.1 reduces overvaluation to 34%, decreasing volatility to 0.7 leaves overvaluation at 37%, and decreasing volatility to 0.5 reduces overvaluation to 34%.

Exit Rate. Higher exit rates increase overvaluation for most of our sample because they bring the guaranteed payoffs of IPO ratchets and liquidation preferences forward. Increasing the exit rate to 0.5 increases overvaluation to 40%. Reducing the exit rate to 0.125 reduces the overvaluation to 29%.

M&A and IPO Exit Probability. IPOs can trigger an 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 assume that IPOs happen for all exits above $1 billion and all other exits are trade sales. This increases median overvaluation to 48%. Alternatively, we could assume that IPOs happen in exactly 50% of unicorn exits. This increases median overvaluation to 38%. Finally, we can assume that the choice between IPO and M&A exit is always made to benefits common shareholders. Unrealistically, this leads to IPOs in almost all cases and overvaluation falls to 23%.

IPO Proceeds. Changing the IPO proceeds has a relatively small impact on overvaluation. When we assume that IPO proceeds are 10% of the IPO amount, overvaluation rises to 42% 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%.

Illiquidity Discount. Investments in private companies are illiquid and may require a return that exceeds the market rate. To test the impact of this, we update the discounted present value of every claim to take into account an annual liquidity premium of γ:[20]

$$\mathbb{E}\left[e^{-T(r_f+\gamma)} f\left(X(0)\ e^{\sqrt{\sigma^2 T}Z+(r_f-\sigma^2/2)T}\right)\right]. \tag{19}$$

A 1% liquidity premium reduces median overvaluation to 35% and a 2% liquidity premium reduces overvaluation to 34%. Adding a liquidity premium has only a small impact on overvaluation because it reduces the values of both common and preferred by approximately the same amount.

[20]The fair value of the company is less than X_0, because X_t increasing at a lower rate than the cost of capital. We set the initial fair value to equal the value of all outstanding claims.

5 Discussion

The value of unicorns and their shares is extremely sensitive to the contractual terms given to investors. This speaks to the importance of information availability for investors, limited partners, and employees. While a small group of privileged investors are aware of these terms and in fact negotiated them, many other stakeholders cannot easily view them and certainly cannot understand the valuation implications.

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 VC deals, yet variations in terms can correspond to large variations in value. Table 9 illustrates the impact on valuation of adding a Qualified IPO restriction that prevents 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. On average, this contractual term increases the overvaluation of these ten companies from 23% to 70%.[21]

The Securities and Exchange Commission (SEC) has similar concerns about unicorn valuations. As Mary Jo White, the 31st Chair of the SEC, stated on March 31, 2016: "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."[22] As an illustration of that sentiment, consider SpaceX's August 2008 Series D round. Despite significant falls in the NASDAQ and the third failed test flight of its satellite launch service, SpaceX's Series D round was an "up" round at $3.88 per share, above the March 2007 Series C price of $3.00 per share.

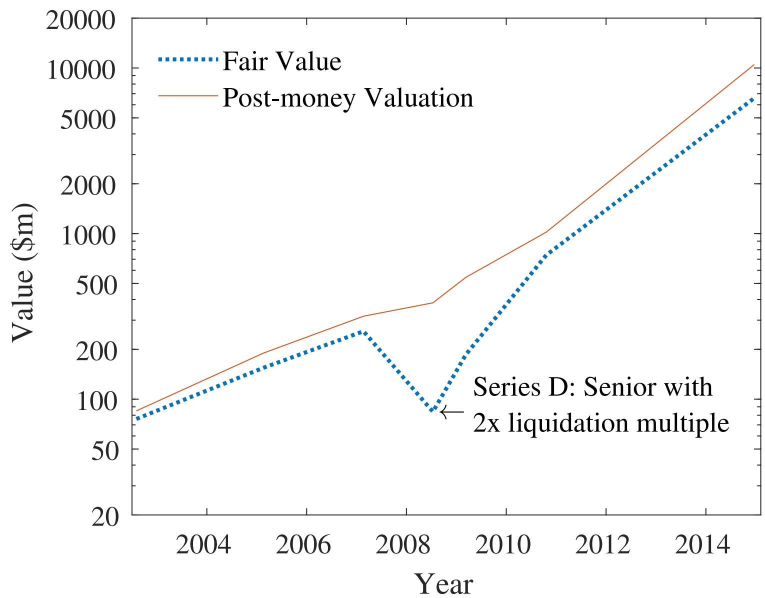
We argue that SpaceX's value actually fell in 2008 and the reported price increase was due to the preferential treatment offered to Series D investors. The Series D investors were promised twice their money back in the event of a sale, with that claim senior to all other shareholders. That guarantee increased the price those investors were willing to pay for SpaceX shares, which increased the company's

[21] It is important to note that we do not have access to all of the contracts between investors and companies. For example, companies often sign side letters with some of the investors that contain additional guarantees. 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.

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

Figure 5: SpaceX Fair Value

This figure compares SpaceX's post-money valuation (solid) with the fair value of the company from our model (dotted). The value is reported using a logarithmic scale. SpaceX's capital structure at each round is reconstructed from its Certificates of Incorporation using the method in Section 3.3 and its fair values are calculated using the model and parameters in Section 2.



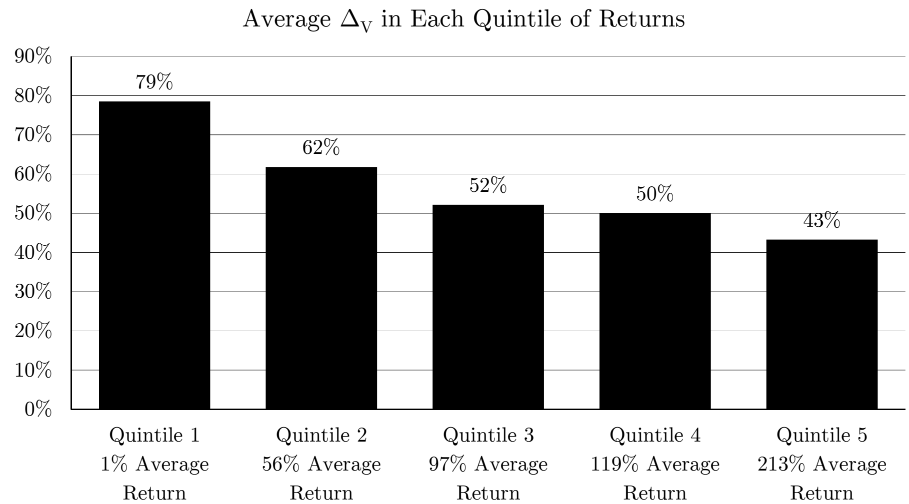
post-money valuation but did not alter its true value. Figure 5 plots out the path of SpaceX's fair value and post-money valuation. Our model shows that these terms caused SpaceX's post-money valuation to rise by 36% despite the true value falling by 67%.

We are not implying that SpaceX structured these deals in order to manipulate its valuation. The Series D contractual terms may have been chosen due to increased levels of asymmetric information or investor risk aversion. However, this example illustrates our concern, shared by the SEC, that poorly performing companies may use more generous securities in a manner that exaggerates their valuations and hides poor performance.

To shed more light on the relevance of these concerns, we can explore the relationship between company overvaluation at the time of the last financing round and the value of its eventual exit. In our main sample, as Table 3 shows, 44 companies exited as of August 1, 2017. For these companies, we record the exit value as the reported M&A value for M&A exits, the opening market capitalization at net of the amount raised for IPO exits, and zero for closed companies. On average, there is an 18 month time gap between the last financing round and the exit. Figure 6 shows that there is a negative relationship

Figure 6: Overvaluation Among Different Levels of Exit Performance

This figure shows the average overvaluation in each quintile of exit returns for the companies in our unicorn sample that had exited as of August 1, 2017. Unicorn capital structures are reconstructed from Certificates of Incorporation using the method in Section 3.3 and fair values are calculated using the model and parameters in Section 2.



between the overvaluation and exit outcomes, where we measure outcomes as the exit value relative to PMV. The lowest quintile of exit returns has average overvaluation 36% above those in the highest quintile of exit returns.

Table 10 shows in addition that overvaluation is a significant predictor of an unsuccessful exit. For the purpose of this table, we define an unsuccessful exit as one in which the exit return is in the bottom tercile. A one standard deviation increase in overvaluation is associated with a 16% higher probability of an unsuccessful exit – a large increase given only 33% of exits are unsuccessful. This further supports the conjecture that substantial overvaluation may result if the relatively struggling companies try to attract investors by introducing a variety of sweetening contractual terms. Note that these results hold despite a very small sample size and a substantial time gap, of on average 18 months, between the last financing round and exit that can give rise to substantial new information about the company's prospects.

IPO ratchets, automatic conversion vetoes, and liquidation preferences have been activated relatively infrequently, as 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 exercised. That will transfer a large amount of value from early investors and common shareholders to the most recent investors in these companies.

6 Conclusion

Valuation of real and financial assets is at the core of finance. In this paper, we develop a valuation model to assess unicorns: young, innovative, and highly-valued companies backed by venture capitalists. We apply our model to value 135 unicorns at the time of their funding rounds. We determine the fair value of these companies, as well as the value of each of the securities they issued. The post-money valuation metric overvalues all unicorns in our sample, but the degree of overvaluation varies dramatically. The average unicorn in our sample is overvalued by 50%. There is a large variation in the degree of overvaluation: while the 10 least overvalued companies are overvalued on average only by 13%, the ten most overvalued companies are on average overvalued by 170%.

Our goal in developing the valuation model and applying it to a sample of unicorns is twofold. First, we hope to attract the attention of academic researchers to the increasingly important issue of the valuation of private companies. Our paper is 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 effort to making 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.

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

This table shows the fair value that produces a post-money valuation of $1b for a unicorn raising a $100m round using different contract 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 priced (FV), and the percentage the post-money valuation formula overstates the value of a common share (Δ_C). Fair values are calculated using the model and parameter values in Section 2.

	Company			Common Share		
Scenario	PMV ($m)	FV ($m)	Δ_V	PMV ($)	FV ($)	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	666	50%	1	0.65	53%
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's Security Values at October 2014

This table lists the post-money valuation and fair value of each class of Square's shares, immediately following the company's $150 million October 2014 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 report the total PMV and FV of each class of shares. The final column (Δ) reports the percentage the post-money valuation formula overstates the value of each class of share. Square's capital structure is reconstructed from Certificates of Incorporation using the method in Section 3.3 and fair values are calculated using the model and parameter values in Section 2.

Security	Shares (m)	Share Price ($) PMV	Share Price ($) FV	Class Value ($m) PMV	Class Value ($m) FV	Δ
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 3: Sample of Unicorns

This table provides summary statistics for past and present U.S. unicorns founded after 1994 with a VC round after 2004. We compare this to our main sample of unicorns for which we have contractual data.

	All Unicorns	Main Sample	Latest COI Unavailable	COI Incomplete
Count	156	135	14	7
Most recent unicorn round				
Date	2014.9	2014.9	2014.6	2014.7
PMV ($m)	3,857	3,322	9,898	2,946
Round size ($m)	256	265	152	277
Number of previous equity rounds	5.6	5.7	4.9	6.1
Amount of equity previously raised ($m)	296	304	254	245
Number of COIs we have	11.2	11.7	5.4	12.7
Founded	2007.5	2007.7	2005.5	2007.4
Based in California	65%	69%	46%	29%
Status (as of Aug 1, 2017)				
Private	105	91	9	5
IPO	35	30	4	1
Acquired	14	12	1	1
Failed	2	2	0	0

Table 4: Prevalence of Special Contract Terms

This table presents data on the prevalence of certain contractual terms in our main sample of unicorns. Contractual terms are reconstructed from Certificates of Incorporation. Seniority classes is the number of seniority classes (e.g., 2 for a company with common equity and one class of Series A Preferred). Major protections are as discussed in Section 2.2 and are the protections given letter codes in the Code column.

	Code	Count	Mean	25th pct	Median	75th pct
Number of unicorns		135				
Preferences Given to Latest Investors						
% of shares new investors senior to			0.64	0.45	0.62	0.88
Senior to some investors		66	0.49			
Senior to all investors	**s**	43	0.32			
Liquidation multiple > 1	**m**	8	0.06			
Participation	**p**	17	0.13			
Cumulative dividends	**d**	9	0.07			
for those, level			0.08	0.06	0.08	0.08
IPO Ratchet	**r**	19	0.14			
for those, level			1.16	1.00	1.00	1.36
Any major protection		75	0.56			
Preferences Given to at Least One Investor						
Seniority	**s**	65	0.48			
Liquidation multiple > 1	**m**	21	0.16			
Participation	**p**	26	0.19			
Cumulative dividends	**d**	15	0.11			
for those, level			0.09	0.06	0.08	0.09
IPO Ratchet	**r**	23	0.17			
for those, level			1.33	1.00	1.25	1.63
Any major protection		93	0.69			
Automatic Conversion Exemptions						
Any exemption		94	0.70			
for those, valuation needed ($m)			931	200	400	1,250
for those, valuation / PMV			0.54	0.11	0.24	1.00
Require valuation		37	0.27			
for those, valuation needed ($m)			1,890	823	1,597	2,346
for those, valuation / PMV			1.12	0.68	1.00	1.50
Require proceeds		92	0.68			
for those, proceeds needed ($m)			86	50	50	100
for those, proceeds / PMV			0.05	0.02	0.04	0.06
Exemption binds in <0.5X IPOs	**o**	32	0.24			

Table 5: Returns to Most Recent Class of Preferred in Down Exits

This table summarizes the returns realized in different exits for the most recent class of preferred shareholders and the common shareholders in our main sample of unicorns. We consider exits at a discount to each financing round's post-money valuation (PMV). Common share returns are expressed relative to the most recent preferred round's share price and a -100% return denotes a complete loss. Unicorn capital structures are reconstructed from Certificates of Incorporation using the method in Section 3.3.

	Return to most recent round				Return to common			
	Mean	25th pct	Median	75th pct	Mean	25th pct	Median	75th pct
M&A exit								
50% below PMV	6%	0%	0%	0%	-63%	-65%	-58%	-55%
75% below PMV	-1%	0%	0%	0%	-91%	-100%	-91%	-85%
90% below PMV	-32%	-52%	-37%	-8%	-99%	-100%	-100%	-100%
IPO exit								
50% below PMV	-25%	-50%	-45%	0%	-57%	-59%	-51%	-50%
75% below PMV	-39%	-75%	-70%	0%	-83%	-92%	-76%	-75%
90% below PMV	-54%	-90%	-57%	-24%	-96%	-100%	-100%	-90%

Table 6: Summary of Unicorns' Fair Values and Post-money Valuations

This table summarizes 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 our main sample of unicorns. Unicorn capital structures are reconstructed from Certificates of Incorporation using the method in Section 3.3 and fair values are calculated using the model and parameter values in Section 2.

	Count	Mean	St. Dev	25th pct	Median	75th pct
PMV ($m)	135	3,322	6,899	1,100	1,530	2,688
FV ($m)	135	2,588	6,143	792	1,049	1,773
Δ_V	135	50%	42%	24%	37%	59%
Δ_C	135	58%	55%	23%	41%	70%

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

This table presents company-level post-money valuations (PMV), fair values (FV), and overvaluations of the valuation (Δ_V) and the common share price (Δ_C) for our main sample of 116 unicorns. The Status column reports whether the company was public '**IPO**', acquired '**Acq**', or closed '**Clsd**' as of August 1, 2017 and is blank if the company remains private. The Special Terms column lists the major protections given to the most recent round (Last Rd) or in any round (Any Rd) using the following letter codes: seniority to all investors '**s**', a liquidation multiple greater than 1 '**m**', participation '**p**', cumulative dividends '**d**', an IPO ratchet '**r**', or if they are the most recent investor and are exempted from conversion in IPOs resulting in returns below 0.5X returns '**o**'. Unicorn capital structures are reconstructed from Certificates of Incorporation using the method in Section 3.3 and fair values are calculated using the model and parameter values in Section 2.

			Valuation ($b)		Overvaluation		Special Terms	
Company	Status	Rd Date	PMV	FV	Δ_V	Δ_C	Last Rd	Any Rd
23andMe		Jul 15	1.1	0.8	40%	41%	s	s
A123 Systems	IPO	May 08	1.1	0.8	39%	41%		ms
Actifio		Jul 15	1.1	0.6	92%	102%	mr	mr
Adaptive Biotech		May 15	1.0	0.8	26%	30%	s	s
Age of Learning		May 16	1.0	0.7	41%	43%	s	
Airbnb		Sep 16	30.0	26.1	15%	10%		
Anaplan		Jan 16	1.1	0.9	23%	22%		
AppDirect		Oct 15	1.4	0.9	46%	49%	s	s
AppDynamics	Acq	Oct 15	1.9	1.3	52%	56%	or	or
Appnexus		Sep 16	1.6	1.1	47%	59%		mrs
Apttus		Sep 16	1.6	1.3	23%	21%		
Automattic		May 14	1.2	0.9	31%	30%		s
Avant		Oct 15	2.0	1.6	24%	29%		
Better Place	Acq	Nov 11	2.3	1.0	120%	180%	dos	dos
Bloom Energy		May 13	3.0	2.7	12%	11%		m
Blue Apron	IPO	Jun 15	2.1	1.6	37%	33%	s	s
Box	IPO	Jul 14	2.6	1.0	164%	208%	mrs	mprs
Buzzfeed		Nov 16	1.7	1.1	57%	71%	rs	rs
Carbon3D		Sep 16	1.1	0.7	45%	52%	o	o
Cloudera	IPO	Mar 14	4.1	3.5	19%	16%		
CloudFlare		Sep 15	3.2	1.6	101%	99%	os	os

Table 7: Detailed Unicorns Fair Values and Post-money Valuations (Continued)

			Valuation ($b)		Overvaluation		Special Terms	
Company	Status	Rd Date	PMV	FV	Δ_V	Δ_C	Last Rd	Any Rd
Compass		Aug 16	1.0	0.8	18%	17%		
ContextLogic		Jun 15	4.0	— COI omits necessary information —				
Coupons.com	IPO	Jun 11	1.0	0.8	19%	20%		s
Credit Karma		Jun 15	3.5	2.8	27%	22%		s
Cylance		Jun 16	1.0	0.7	46%	49%	o	o
Datto		Nov 15	1.0	0.4	126%	144%	dr	dr
Delphix		Jul 15	1.0	0.7	48%	47%	s	s
Demand Media	IPO	Mar 08	1.2	0.6	110%	164%	dos	dos
Denali Therap.		Jun 16	1.1	0.9	31%	37%	d	d
Docker		Nov 15	1.1	0.9	26%	25%		
DocuSign		May 15	3.0	2.3	31%	30%	p	mp
Domo		Mar 16	2.2	1.9	17%	16%		s
DraftKings		Aug 15	2.0	1.5	35%	43%	o	os
Dropbox		Jan 14	10.4	8.6	21%	16%		
Elevance Rnw. Sc.	Acq	Aug 14	1.2	0.7	66%	130%	dps	dps
Eventbrite		Mar 14	1.2	0.9	27%	25%		s
Evernote		May 15	1.7	1.1	54%	58%	o	dop
Fab.com	Acq	Jun 13	1.2	1.0	19%	20%		
Fanatics		Aug 15	2.7	1.7	64%	80%	os	os
FireEye	IPO	Jan 13	1.3	0.8	47%	43%		
Flatiron Health		Jan 16	1.2	1.0	21%	20%		
Flipboard		Jul 15	1.3	0.7	95%	114%	mr	mr
Forescout Tech		Nov 15	1.0	0.6	73%	91%	os	ops
Genius Media		Jul 14	1.0	— COI omits necessary information —				
Github		Jul 15	2.0	1.6	22%	20%		
Good Technlgy.	Acq	Apr 14	1.2	0.5	147%	193%	pr	pr
GoPro	IPO	Dec 12	2.3	2.1	5%	0%		

Table 7: Detailed Unicorns Fair Values and Post-money Valuations (Continued)

			Valuation ($b)		Overvaluation		Special Terms	
Company	Status	Rd Date	PMV	FV	Δ_V	Δ_C	Last Rd	Any Rd
Groupon	IPO	Jan 11	4.8	4.1	16%	14%	s	s
HomeAway	IPO	Oct 08	1.7	0.8	110%	182%	mrs	dmprs
Hortonworks	IPO	Jul 14	1.4	1.1	32%	33%		
Houzz		Oct 14	2.3	1.8	27%	23%		
Human Longevity		Apr 16	1.9	1.5	23%	21%		
Illumio		Apr 15	1.0	0.8	30%	28%		
Insidesales.com		Jan 17	1.7	1.4	25%	23%		
Instacart		Dec 14	2.0	1.6	23%	21%		
Intarcia Therap.		Sep 16	3.9	2.9	36%	36%	s	s
Intrexon	IPO	May 13	1.1	0.6	71%	123%	dps	dps
Jasper Wireless	Acq	Apr 14	1.4	0.8	81%	83%	s	s
Jawbone	Clsd	Jan 16	1.5	1.1	35%	65%		mps
Jet.com	Acq	Nov 15	1.6	1.3	24%	37%	o	do
JetSmarter		Dec 16	1.6	1.1	52%	50%		
JustFab		Aug 14	1.0	0.5	111%	190%	prs	mprs
Kabam	Acq	Aug 14	1.0	0.6	61%	73%	os	os
Kabbage		Jul 15	1.0	0.6	61%	72%	ds	ds
Kendra Scott		Jul 14	1.0	0.3	267%	279%	ops	op
LendingClub	IPO	Apr 14	3.7	2.5	50%	46%	p	p
LifeLock	IPO	Mar 12	1.0	— COI omits necessary information —				
LinkedIn	IPO	Jun 08	1.0	0.6	59%	59%	o	o
LivingSocial	Acq	Feb 13	1.5	— COI omits necessary information —				
Lookout		Aug 14	1.7	1.4	23%	21%		
Lumeris		May 14	1.2	0.7	62%	104%	op	mops
Lyft		Dec 15	5.5	4.9	11%	10%		
Lynda.com	Acq	Jan 15	1.0	0.7	39%	47%	r	r
Machine Zone		Aug 16	5.6	4.4	26%	24%		

Table 7: Detailed Unicorns Fair Values and Post-money Valuations (Continued)

			Valuation ($b)		Overvaluation		Special Terms	
Company	Status	Rd Date	PMV	FV	Δ_V	Δ_C	Last Rd	Any Rd
Magic Leap		Feb 16	4.5	3.0	50%	63%	os	os
MarkLogic		May 15	1.2	0.9	34%	31%		s
Medallia		Jul 15	1.3	1.0	25%	24%		s
MediaMath		May 14	1.1	0.6	79%	81%	os	dos
Moderna		Aug 16	4.7	3.9	21%	19%	s	ds
MongoDB		Jan 15	1.8	1.5	24%	22%		
Mozido		Aug 15	2.4	— COI omits necessary information —				
Mu Sigma		Mar 16	1.5	— COI omits necessary information —				
MuleSoft	IPO	May 15	1.5	1.2	26%	25%	p	p
New Relic	IPO	Apr 14	1.5	1.0	45%	44%		s
Nextdoor		Mar 15	1.1	0.9	25%	23%		
NJOY		Oct 15	1.3	0.8	53%	67%	d	ds
Nutanix	IPO	Aug 14	2.0	0.8	155%	199%	rs	mrs
OfferUp		Sep 16	1.3	0.9	38%	38%	s	s
Okta	IPO	Sep 15	1.2	1.0	25%	23%		
OnLive	Acq	Mar 12	1.9	1.3	42%	44%	s	ps
OpenDoor		Dec 16	1.1	0.8	36%	45%	o	o
Oscar		Feb 16	2.7	1.9	43%	49%	r	r
Palantir		Dec 15	20.5	17.8	15%	11%		
Pinterest		May 15	11.4	9.5	19%	15%		
Pivotal		May 16	3.3	2.2	46%	58%	rs	rs
Planet Labs		Jul 15	1.1	0.7	62%	71%	os	os
Procore Tech.		Dec 16	1.0	0.7	43%	45%	o	o
Prosper		Apr 15	1.9	1.2	56%	59%	o	ops
Proteus Dgtl Hlth		Apr 16	1.5	1.2	31%	39%	p	ps
PURE Storage	IPO	Apr 14	2.9	2.4	22%	19%		
Qualtrics		Sep 14	1.0	0.8	32%	78%	opr	oprs

Table 7: Detailed Unicorns Fair Values and Post-money Valuations (Continued)

			Valuation ($b)		Overvaluation		Special Terms	
Company	Status	Rd Date	PMV	FV	Δ_V	Δ_C	Last Rd	Any Rd
Quanergy Syst.		Aug 16	1.6	0.9	85%	85%	os	os
Roku		Nov 15	1.5	0.5	191%	267%	ops	oprs
Silver Spring	IPO	Dec 09	2.9	1.6	80%	85%	mr	mrs
SimpliVity	Acq	Mar 15	1.2	0.8	41%	47%	o	o
Slack		Apr 16	3.8	3.2	19%	15%		s
Snap	IPO	May 16	20.0	19.0	5%	0%		
Social Finance		Aug 15	3.6	2.8	27%	39%	o	dmo
SolarCity	IPO	Feb 12	1.9	0.7	172%	198%	rs	rs
Solyndra	Clsd	Aug 09	1.5	0.9	60%	167%	ops	ops
SpaceX		Jan 15	10.5	6.6	59%	61%	o	mos
Sprinklr		Jul 16	1.8	1.3	37%	35%		p
Square	IPO	Oct 14	6.0	2.3	165%	171%	rs	rs
Stemcentrx	Acq	Sep 15	5.0	4.2	18%	15%		r
Stripe		Nov 15	9.2	— COI omits necessary information —				
Sunrun	IPO	May 14	1.3	0.8	62%	73%	os	os
TangoMe		Mar 14	1.1	0.8	39%	52%	os	os
Tanium		Sep 15	3.7	2.8	31%	27%		
The Honest Co		Aug 15	1.7	1.2	40%	42%	r	mr
Theranos		Mar 15	10.5	8.0	31%	28%	p	ps
Thumbtack		Sep 15	1.3	1.0	24%	22%		
Twilio	IPO	Jul 15	1.1	0.9	26%	26%		
Twitter	IPO	Aug 11	9.3	7.6	21%	16%		s
Uber		Jun 16	68.0	60.6	12%	8%		mr
Udacity		Nov 15	1.0	0.7	35%	33%	s	s
Unity Software		Jul 16	1.5	1.1	37%	37%		
Uptake		Oct 15	1.1	0.4	187%	196%	dms	dms
Violin Memory	IPO	Feb 13	1.1	0.8	37%	42%	ms	ms

Table 7: Detailed Unicorns Fair Values and Post-money Valuations (Continued)

			Valuation ($b)		Overvaluation		Special Terms	
Company	Status	Rd Date	PMV	FV	Δ_V	Δ_C	Last Rd	Any Rd
Vox Media		Aug 15	1.1	0.8	29%	36%	p	p
Warby Parker		Apr 15	1.2	1.0	25%	23%		
WeWork		Mar 17	18.0	15.3	18%	13%		s
WhatsApp	Acq	Jul 13	2.7	1.7	58%	54%	p	p
Workday	IPO	Oct 11	1.8	1.2	51%	51%	s	ps
Zenefits		May 15	4.5	3.7	20%	17%		
ZenPayroll		Dec 15	1.1	0.9	26%	24%		
Zocdoc		Aug 15	1.8	1.3	35%	36%		
Zoom Video		Jan 17	1.0	0.5	107%	144%	op	ops
Zoox		Oct 16	1.6	1.1	39%	43%		
Zscaler		Aug 15	1.1	0.6	77%	90%	mor	mor
Zulily	IPO	Nov 12	1.1	0.8	38%	37%		
Zynga	IPO	Feb 11	8.0	6.5	23%	19%	s	s

Table 8: Overvaluation Under Robustness Checks

Table 8 reports the mean, median, and quartiles of overvaluation under different scenarios. These statistics are calculated across our main sample of unicorns. Unicorn capital structures are reconstructed from Certificates of Incorporation using the method in Section 3.3. Our baseline model and parameter assumptions are described in Section 2. Our baseline estimates assume company values follow a geometric Brownian motion with volatility of 0.9, drift at a risk free of 2.5%, and exits at a Poisson rate $\lambda = 0.25$.

	Mean	St. Dev	25th pct	Median	75th pct
Baseline	50%	42%	24%	37%	59%
Valuation Errors					
Real PMV 20% above reported	54%	46%	26%	39%	60%
Real PMV 20% below reported	45%	37%	23%	34%	53%
Investment Amount Errors					
All authorized preferred issued	49%	39%	25%	37%	57%
Unissued Options					
ESOP is 0% of PMV	43%	41%	19%	30%	51%
ESOP is 10% of PMV	57%	43%	31%	44%	67%
Issued Options					
25% of common are options	53%	44%	27%	39%	61%
50% of common are options	56%	47%	30%	42%	65%
Debt					
5% Leverage	39%	30%	21%	30%	45%
10% Leverage	31%	22%	17%	25%	36%
Indifference to Future Financing					
Cramdowns 10% of the time	42%	32%	22%	32%	50%
Cramdowns 25% of the time	35%	24%	20%	28%	42%
Hold up in IPOs					
Exercised 50% of the time	44%	37%	23%	32%	46%
Never exercised	40%	37%	22%	27%	39%

Table 8: Valuations Under Robustness Checks (Continued)

	Mean	St. Dev	25th pct	Median	75th pct
Volatility					
$\sigma = 0.5$	77%	124%	21%	34%	64%
$\sigma = 0.7$	60%	64%	25%	37%	64%
$\sigma = 1.1$	42%	30%	23%	34%	50%
Exit Rate					
$\lambda = 0.5$	67%	77%	26%	40%	72%
$\lambda = 0.125$	35%	23%	20%	29%	42%
M&A and IPO Exits					
$p^{IPO}(X) = \mathbb{I}[X > \$1b]$	61%	58%	36%	48%	71%
$p^{IPO}(X) = 50\%$	50%	40%	25%	38%	60%
Choice that benefits common	37%	42%	6%	23%	52%
IPO Proceeds					
IPO proceeds of $0.1X(T)$	53%	41%	26%	42%	62%
IPO proceeds of $0.5X(T)$	49%	42%	24%	34%	55%
Risk-free Rate					
$r_f = 0\%$	57%	50%	26%	41%	66%
$r_f = 5\%$	44%	35%	23%	33%	52%
Illiquidity Premium					
Annual 1% illiquidity premium	47%	39%	24%	35%	55%
Annual 2% illiquidity premium	45%	36%	23%	34%	51%

Table 9: Impact of Hypothetical Qualified IPO Restrictions on Overvaluation

This table reports the impact of qualified IPO restrictions on the fair values of the largest ten VC-backed companies that were private as of August 1, 2017. The first two columns list the post-money valuation (PMV) and round date of each company's most recent round. The next two columns use the cash flows described in each company's Certificate of Incorporation to determine that company's fair value (FV) and the extent the post-money valuation overstates the value (Δ_V). The following two columns report the fair value and overvaluation under the assumption that the most recent investors had a veto over down-IPOs. Unicorn capital structures are reconstructed from Certificates of Incorporation using the method in Section 3.3 and fair values are calculated using the model and parameter values in Section 2.

			Cash Flows Described in COI		Assuming Restriction on Qualified IPOs	
Names	PMV	Date	FV	Δ_V	FV	Δ_V
Uber	68.0	Jun 16	60.6	12%	44.8	52%
Airbnb	30.0	Sep 16	26.1	15%	18.3	64%
Palantir	20.5	Dec 15	17.8	15%	13.0	58%
WeWork	18.0	Mar 17	15.3	18%	11.1	63%
Pinterest	11.4	May 15	9.5	19%	7.0	63%
SpaceX	10.5	Jan 15	6.6	59%	6.3	65%
Theranos	10.5	Mar 15	8.0	31%	3.9	165%
Dropbox	10.4	Jan 14	8.6	21%	5.7	83%
Machine Zone	5.6	Aug 16	4.4	26%	3.5	61%
Lyft	5.5	Dec 15	4.9	11%	4.4	26%
Average				23%		70%

Table 10: Relationship Between Overvaluation and Failure

This table reports the determinants of failure for the VC-backed companies that had exited as of August 1, 2017. We define failure as having an exit in the bottom tercile of exit returns. This is equivalent to an M&A exit at least 41% below the most recent PMV or an IPO with net proceeds value 41% or more below the PMV. Specifications (1) and (2) are under OLS. Specifications (3) and (4) are under Logit. The independent variables are the log of the post-money valuation, the amount raised in the most recent round, the number of years between financing and exit, the return on the S&P 500 between the investment and the exit, the year the company was founded, and a dummy variable equal to one if the company is based in California. An asterisk (*) denotes significance at the 10% level; (**) the 5% level. Unicorn capital structures are reconstructed from Certificates of Incorporation using the method in Section 3.3 and fair values are calculated using the model and parameter values in Section 2.

	OLS		Logit	
	(1)	(2)	(3)	(4)
Δ_V	0.33**	0.38**	1.45**	1.77**
	(0.15)	(0.18)	(0.74)	(0.83)
Log PMV		-0.12		-0.64
		(0.15)		(0.72)
Log Amount Raised		0.10		0.50
		(0.15)		(0.69)
Time to Exit		-0.06		-0.31
		(0.13)		(0.60)
Market Return		0.32		1.93
		(0.61)		(3.10)
Year Founded		0.02		0.09
		(0.04)		(0.19)
Based in California		0.08		0.41
		(0.20)		(0.93)
Observations	44	44	44	44
Adjusted R^2	7.8%	-3.7%		
R^2	9.9%	13.2%		