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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 US unicorns, that is, private companies with reported valuations above $1 billion. We value unicorns using financial terms from legal filings and find that reported unicorn post-money valuations average 48% above fair value, with 14 being more than 100% above. Reported valuations assume that 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 initial public offering (IPO) return guarantees (15%), vetoes over down-IPOs (24%), or seniority to all other investors (30%). Common shares lack all such protections and are 56% 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 US since the late 1970s, a third had venture capital backing.[1] 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 could become the next Google or Facebook. The growth of these companies spawned the

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[1] Ritter (2015) reports 32% for 1980–2013 and 33% for 1980–2017 (see Table 4c in https://site.warrington.ufl.edu/ritter/files/2018/01/IPOs2017Statistics_January17_2018.pdf, retrieved on May 1, 2018). Gornall and Strebulaev (2015) report that 43% of public companies founded after 1974 had venture capital backing.

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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 one hundred unicorns in the US and another one hundred in other countries.[2]

With the reported valuation of these unicorns totaling more than $700 billion, the interest in VC as an asset class has increased substantially. A number of the largest US mutual fund families, such as Fidelity Investments and T. Rowe Price, have begun investing 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 with the size of the mutual fund industry, a tenfold increase has taken place in just three years. In 2015, Fidelity invested more than $1.3 billion into unicorns, more than any US VC fund invested that year.[3]

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 also by sophisticated insiders.

Unlike public companies, which generally have a single class of common equity, VC-backed companies typically create a new class of equity every 12–24 months when they raise money. The average 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.

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 also 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. 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 in which the company raised $150 million by issuing 9.7 million Series E Preferred Shares for $15.46 per share to a variety of investors.[4] 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 initial public offering (IPO), with both of those claims senior to all other shareholders. These Series E shares joined Square's existing common shares 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 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:

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

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*.[5]

The post-money valuation formula in Eq. (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 some 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

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

[3] Calculated from Center for Research in Security Prices 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 $113 million in Nutanix.

[4] In the VC industry, subsequent rounds of funding are traditionally ordered alphabetically. Thus, Series E would typically be preceded by rounds in which Series A, B, C, and D were raised.

[5] 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, and http://www.economist.com/news/finance-and-economics/21678809-profitless-payment-firm-goes-public-swiped, all accessed November 15, 2016.

distinct cash flow rights. VC-backed companies issue a variety of shares with different terms, which means that these shares have different values and a formula like Eq. (1), where all classes are assumed to have the same value, cannot be used. In many cases, the most recent VC investors have been given what is essentially a put option, a right that transfers substantial value to them at a direct cost to the unprotected shareholders.

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.

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 company'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 US unicorns and find that post-money valuations overstate company values in all cases, with the degree of overvaluation ranging from 5% to a staggering 188%. To do so, we extract contractual terms of unicorns from certificates of incorporation (COI) 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. Section 4 contains the core of the paper's findings, showing the overvaluation of all US unicorns in our sample, as of the time of their most recent round (see Tables 6 and 7).

Our results show that equating post-money valuations and fair values is inappropriate. Although valuation practices are secretive and idiosyncratic, several limited partners (LPs) have informed us that most venture capital funds mark all of their investments to the most recent round's price. An informal survey of VCs we conducted also suggests that many of them mark up their investments after subsequent successful rounds in their reports to LPs. This is consistent with a memo written for one of the major venture capital firms, Andreessen Horowitz, in which its partner Scott Kupor argues that "[s]ome venture firms value their companies by taking the last round company valuation in the private market and assigning that value to the firm's ownership in that company." Moreover, because Andreessen Horowitz uses a valuation methodology that takes into account contractual terms, its "marks are deliberately more conservative and according to our LPs are lower than other firms who use different methods". Our survey is also consistent with an industry report by the data provider Sandhill Econometrics, which asserts that "in reporting company value, [VC investors] ignore preferences and report all shares at the same value."[6] We can get better disclosure from venture capital vehicles that market themselves to the public in Europe. Two of the largest such vehicles explicitly note that they mark their values to the price of the most recent round.[7] Marking unicorns to their most recent round's price leads some venture capitalists to overstate their fund's unrealized value. As unrealized asset values are an important determinant of future fund-raising (Barber and Yasuda, 2017), this could lead the investors in venture capital funds to misallocate capital.

Mutual fund filings show even more clearly the prevalence of treating post-money valuations as fair values. 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.[8] We find the D-1 shares were worth 43% more. Along the same lines, most mutual funds write up all of their share holdings of a given unicorn to the price of its most recent round of funding, regardless of the type of stock. For example, 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 its Series E shares to the Series F price despite not being eligible for the 20% bonus.[9] These examples are representative of common industry practices. Mutual funds have earned large mark-to-market returns on their venture capital investments [see, e.g., Agarwal et al. (2017)]. These returns would be lower with more appropriate valuation methodologies.

As another example, secondary equity sales site EquityZen describes the prices of common stock in terms of the price that 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.[10]

> 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.

[6] Available at http://sandhillecon.com/pdf/MeasuringRiskForVentureAndBuyouts.pdf, accessed February 22, 2018.

[7] See, for example, these filings by Draper Esprit (the largest publicaly traded VC fund) on p. 76 of http://draperesprit.com/wp-content/uploads/2015/12/Admission-Document-Draper-Esprit-plc-1.pdf or by Octopus Titan (the largest UK venture capital trust) at 15.11 of https://octopusinvestments.com/investor/investor-centre/document-library/octopus-titan-vct-prospectus/, both retrieved February 2, 2018.

[8] See https://www.sec.gov/Archives/edgar/data/1331971/000114544316001402/d299215.htm, accessed January 27, 2017.

[9] See https://www.sec.gov/Archives/edgar/data/880366/000119312516514406/d102719dnq.htm, accessed October 19, 2017.

[10] Retrieved from https://equityzen.com/invest/1037572/ on September 14, 2016. Emphasis in original.

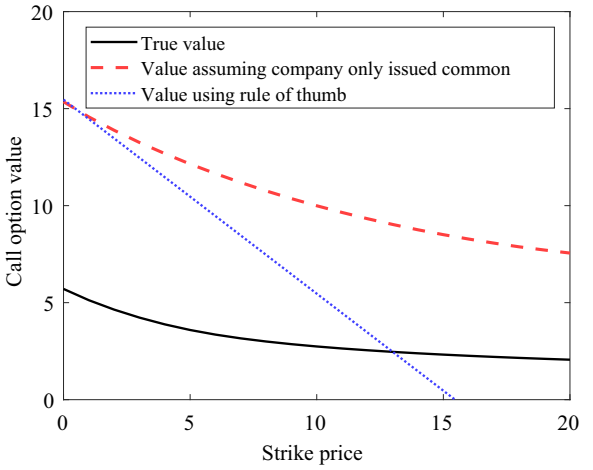

Fig. 1. Value of options on Square's common shares. This figure reports the value of options on Square's common stock, as of the company's October 2014 Series E round. The solid line shows the fair value of an option with varying strike price. The dashed line shows the value of that option if Square had only common shares. The dotted line shows the value of that option using a naive 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.

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.[11] Fig. 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 that 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.

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 buyers of Series D shares 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 fundraising 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 determine 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).

The 409A tax valuations of VC-backed companies often rely on similar techniques. The primary goal of these valuations is tax compliance, not strategic insight. Many companies push their 409A providers for lower valuations as this allows them greater freedom in setting option strike prices. This pressure leads to the use of assumptions that produce conservative valuations.[12] 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%.[13] As another example, Economics Partners, which provides both strategic and tax valuations, indicated to us that 409A valuations of VC-backed companies with at least three rounds of preferred funding have common shares worth an average of 35% of the value of preferred shares, which implies average overvaluation of at least 185% for common shares.

Metrick and Yasuda (2010b) provide a textbook treatment of the venture capital industry. In particular, in

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

[12] 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.

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

chapters 13–15 and 17–18 they discuss the nature of post-money valuation and its difference from fair value and describe the contingent claims approach to post-money valuation. They also analyze the pricing implications of a number of contractual features, such as liquidation preferences, for the most important securities used in the VC-backed transactions. We apply the contingent claims framework to analyze quantitatively the relation between fair value and post-money valuation and value specific VC-backed companies. In doing so, we also value many additional contractual features, such as IPO ratchets.

We also develop methodology to reconstruct the 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 branches of the literature on venture capital. Cochrane (2005), Harris et al. (2014, 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, many papers that look at project-level returns [including Cochrane (2005) and Korteweg and Sorensen (2010)] take post-money valuations at face value and use them as a proxy for fair value, a practice that we caution against. Chung et al. (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 et al. (2019), and Chakraborty and Ewens (2018) examine how venture capitalists report the value of their stakes to their investors. Agarwal et al. (2017) and Kwon et al. (2017) explore the way that mutual funds mark their VC investments and their exit performance. Cumming (2008), Hsu (2004), and Kaplan and Strömberg (2003, 2004) explore VC contracting and the economics behind contractual terms. Our findings of significant overvaluation are not inconsistent with the views of VCs themselves. A survey of VCs by Gompers et al. (2019) shows that 91% of VCs think that unicorns are overvalued.

As our paper argues these securities are reported at incorrect values, our work is also related to classic literatures on mispricing and misreporting. Anomalies papers such as Lamont and Thaler (2003), French and Poterba (1991), Bondt and Thaler (1985) and Ritter (1991) [see Schwert (2003) for a survey] argue for occasional mispriced stocks. Papers such as Barth (1994), Carroll et al. (2003), and Plantin et al. (2008) discuss the effect and importance of mark-to-market accounting. To the extent that freedom in setting contractual terms allows arbitrary valuations to be hit, our paper is related to earnings management papers such as Dechow et al. (1995), Healy (1985), and DeFond and Jiambalvo (1994).

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 Subsection 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 a company at the time of that round. Consider a company that raises a financing round of amount I at time 0. The company exits at value $X(T)$ at some time T in an IPO, a merger or an acquisition (M&A), or a liquidation. All shareholders are paid out at exit, with the investor's payoff being a function of the exit amount, $f(X(T))$.[14] 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.

To discount future cash flows at the time of exit, 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 under the 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) use 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:

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

Because $X(t)$ is a geometric Brownian motion, we can rewrite Eq. (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 Eq. (3) and fairly prices the round.

Investments in VC-backed companies are traditionally priced in terms of 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 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

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

and unconverted payoffs:

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

More generically, if more than one class of claimants 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 doing so reduces their payout (e.g., the IPO share price is below the share price at which the preferred shareholders invested).

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

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

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

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

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:

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

According to industry practitioners, a company could find going public difficult 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 force an M&A exit.

We consider a single financing round. 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 subsection, we introduce the key cash flow terms used in the financings of VC-backed companies and discuss 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 subsection 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 provisions 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 in a Series B round with a post-money valuation of \$1 billion using standard preferred shares with a conversion option, automatic conversion in IPOs, a guaranteed 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 in a Series A round with a post-money valuation of \$450 million using the preferred shares with the same rights and terms as, and pari passu seniority with, the newly issued shares.[15] Using subscripts to denote the different rounds, $P_A = 450$, $P_B = 1,000$, $I_A = 50$, and $I_B = 100$ (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%.[16] For these capital structure inputs, the payout to the new investor in an IPO is the converted payoff in Eq. (6) and in an M&A exit or liquidation is the following function of the exit value X:[17]

$$f_B^{M\&A}(X) = \max\left\{\min\left\{\frac{I_B}{I_A + I_B}X, I_B\right\}, X \times \frac{I_B}{P_B}\right\}. \quad (8)$$

Eq. 8 is the standard formula for the valuation of convertible preferred security at maturity, for an all-equity firm. 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 implied fair value. 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 that 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%.[18]

[15] Pari passu seniority means that all classes of preferred equity that do not convert have the same priority in liquidation and the same recovery rate.

[16] On a fully diluted basis, old investor's ownership is $I_A/P_A(1 - I_B/P_B)$.

[17] Generically, payoff formulas could be substantially more complicated as the conversion decisions of various investors are interdependent. For the cases considered in this subsection, the Series A investor finds it optimal to convert in all the cases in which the Series B investor converts. See Section 2.3 for discussion of how the model implements the generic case.

[18] Even though common stock is junior, its overvaluation could be less than that of the entire company because of the option pool effect. As the option pool becomes larger, more nonexistent shares are included in the

Table 1
Impact of contract terms on fair value.
This table shows the fair value that produces a post-money valuation of $1 billion for a unicorn raising a $100 million round using different contract terms. The "Company" columns report the post-money valuation of the new round (PMV) in millions of dollars, the fair value of the company that makes that round fairly priced (FV) in millions of dollars, and the percentage by which the post-money valuation overstates the fair value (Δ_V). The "Common share" columns report the share price of the round (PMV) in dollars, the fair value of the common shares (FV) in dollars, and the percentage by which the share price overstates the value of common shares (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	1000	771	30%	1	0.78	28%
Liquidation multiple						
1.25X	1000	705	42%	1	0.70	43%
1.5X	1000	638	57%	1	0.62	61%
2X	1000	515	94%	1	0.48	109%
Option pool						
0%	1000	810	23%	1	0.78	28%
10%	1000	732	37%	1	0.78	28%
Seniority						
Junior	1000	811	23%	1	0.82	22%
Senior	1000	737	36%	1	0.74	35%
Participation						
With no cap	1000	653	53%	1	0.64	56%
With 2.5X cap	1000	666	50%	1	0.65	53%
IPO Ratchet						
At 1X	1000	640	56%	1	0.62	60%
At 1.25X	1000	573	75%	1	0.55	83%
At 1.5X	1000	508	97%	1	0.47	114%
Automatic conversion veto						
At 1X	1000	646	55%	1	0.63	59%
At 0.75X	1000	651	54%	1	0.63	58%
At 0.5X	1000	680	47%	1	0.67	50%
Investment amount						
$400 million in round 2	1000	875	14%	1	0.85	17%
$10 million in round 2	1000	698	43%	1	0.72	39%
$400 million in round 1	1000	885	13%	1	0.87	14%
$10 million in round 1	1000	745	34%	1	0.76	32%

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

$$f_B^{M\&A}(X) = \max\left\{\min\left\{\frac{L \times I_B}{I_A + L \times I_B}X, L \times I_B\right\}, X \times \frac{I_B}{P_B}\right\}. \quad (9)$$

As the equation indicates, if the firm value is worth less than the guaranteed amount, the investors receive less than the guaranteed amount. 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%, and giving the new investor 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. Instead of 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.

company's post-money valuation, resulting in more overvaluation for the company and with potentially little change in the common stock value.

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 that no unissued shares are 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 because of the option pool effect. 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 in which preferred shares have few additional rights, the round price can 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:

$$f_B^{M\&A}(X) = \max\left\{\min\{X, I_B\}, X \times \frac{I_B}{P_B}\right\}. \tag{10}$$

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 an existing investor:

$$f_B^{M\&A}(X) = \max\left\{\min\{X - I_A, I_B\}, X \times \frac{I_B}{P_B}\right\}. \tag{11}$$

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

Participation. Participation terms give 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 (with $C \geq 1$), and, to get a payoff in excess of C, the investors must convert. Several unicorns use this term, such as Proteus Biomedical for which all preferred shares enjoy uncapped participation or Sprinklr for which the Series B Preferred Shares participate with a 3X cap and the Series C Preferred Shares participate with a 2X cap. Even in our simple illustrative case, the payout formula is complicated, as caps result in a multi-kinked payoff function:

$$f_B^{M\&A}(X) = \begin{cases} \max\left\{\min\left\{I_B, \frac{I_B}{I_A+I_B}X\right\}, I_B + \frac{(X-I_B-I_A)\times I_B/P_B}{1-I_A/P_A\times(1-I_B/P_B)}\right\} & \text{if Series A does not convert} \\ \max\left\{\min\left\{CI_B, I_B + (X-I_B)\times\frac{I_B}{P_B}\right\}, \frac{I_B}{P_B}X\right\} & \text{if Series A converts,} \end{cases} \tag{12}$$

where Series A converts if

$$X_A > I_B + \frac{P_A}{1 - I_B/P_B}. \tag{13}$$

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, e.g., 50% overvaluation persists even with the common 2.5X cap. The effect is small because we consider a highly valued company for which 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 preagreed 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

$$f_B^{IPO}(X) = \max\left\{\min\{X, R \times I_B\}, X \times \frac{I_B}{P_B}\right\}. \tag{14}$$

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 veto. 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 paid the highest per share price and thus have the highest liquidation preference amount. 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 Shares an exemption for IPOs priced below $18.1755 per share or with proceeds below $50 million, Series B Preferred Shares an exemption for IPOs with proceeds below $50 million, Series C Preferred Shares an exemption for IPOs with proceeds below $75 million, and Series D Preferred Shares an exemption for IPOs with proceeds below $100 million.

In many cases, additional terms can allow a majority of preferred shares voting together to force the conversion of preferred shares, even without 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 exemptions 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

$$f_B^{IPO}(X) = \begin{cases} f_B^{M\&A}(X) & if\, f_B^{M\&A}(X) > X \times \frac{I_B}{P_B} \\ X \times \frac{I_B}{P_B} & \text{otherwise} \end{cases}. \tag{15}$$

Table 1 shows that overvaluation of 55% results if the new investor is exempted from converting in all down-exits. Even exemptions that bind only on low IPOs, such as those below 50–75% of the post-money valuation, lead to 47%–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 $I_B = \$400$ million leads to an overvaluation of 14%. At the other extreme, if the new investor only invested \$10 million, the overvaluation rises to 43%.

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 fewer common shares, the new shares are less senior and overvaluation falls, as illustrated in Table 1, where the last rows hold share prices fixed and vary the first round's investment amount.

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 \$30 million 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:

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

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 \$2.2 billion at the time of its \$6 billion Series E round. Square's Series E shares were worth three times as much as its common shares and its Series A and B shares. Square's unissued stock options were worth nothing because they were not part of the company's value. These options could be issued in the future in exchange for labor. However, future labor compensation is not part of present 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 \$30 million of Series E securities in 2015, which pushed its post-money valuation up to \$6.03 billion and its fair value up to \$2.3 billion.

In November 2015, Square went public at \$9 per share with a pre-IPO value of \$2.66 billion, substantially less than its \$6 billion 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 highly overvalued. As we show in Section 5, high overvaluation predicts exits at values below the previous round's post-money valuation.

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 straightforward based on the probability distributions in Section 2.4. What is challenging is calculating the payoffs themselves.

Calculating payoffs is not always clear-cut, 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 the choice of whether to convert.

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 into which each class converts 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 when different investors have dominant positions in more than one share class. While we have good data on the identity of investors for most unicorns, we cannot verify how much they 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

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 "Shares" column gives the number of shares in each class, in millions. The "Share price" columns report the share price on a post-money valuation (PMV) and fair value (FV) basis, in dollars. The "Class value" columns report the total PMV and FV of each class of shares, in millions of dollars. The final column (Δ) reports the percentage, by which 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.

	Shares	Share price ($)		Class value ($m)		
Security	(m)	PMV	FV	PMV	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	3608	1311	175%
Unissued options	19	15.46	0.00	300	–	–
Total		15.46	6.00	6000	2211	171%

iterating in order of seniority, paying the liquidation preference of each class of shares in that seniority class that chooses not to convert. After liquidation payouts, the surplus cash is distributed prorata to common equity, converted preferred shares, and participating shares. We limit the payoff of participating shares to their cap and distribute the resulting surplus across common equity and any participating shares that have not hit their cap. Shares with cumulative dividends have those dividends added to their final payout.

2.4. Parameters

In this subsection, 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 more of a challenge 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, 2010b). 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.[19]

An argument could be made for somewhat lower volatility to account for the late-stage and developed status of unicorns. These large companies may 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 relation between stage and volatility for VC-backed companies.

The relation 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 good data on the dates of funding rounds, IPOs, and M&As, the dates of failures are generally not reported and companies are reported as 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 late-stage companies, we consider only companies with at least four rounds of VC financing. We have data on 10,523 companies and reported exits for 4649 of them. For the companies that report an exit, the average time between the fourth round and an exit is 3.9 years and the time between the sixth round and an 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 four years. Metrick and Yasuda (2010a) use a similar exponential distribution

[19] All of these researchers take post-money valuations as fair values when calculating volatility. How overvaluation would impact volatility estimates in a fully formed selection model is unclear.

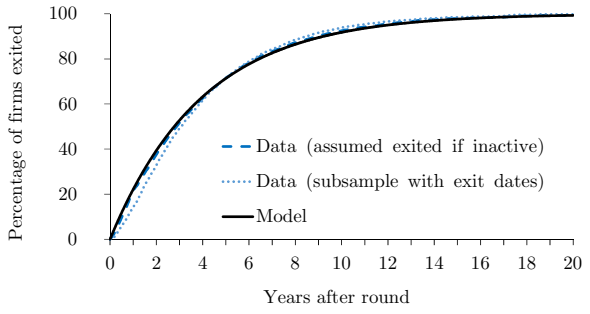

Fig. 2. Time to exit dispersion in VentureSource and model. This figure reports the percentage of firms that have exited at different times after a financing round. Our model (solid line) has firms exit at an exponential rate of $\lambda = 0.25$. This is compared with the time to exit for fourth or later venture capital 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.

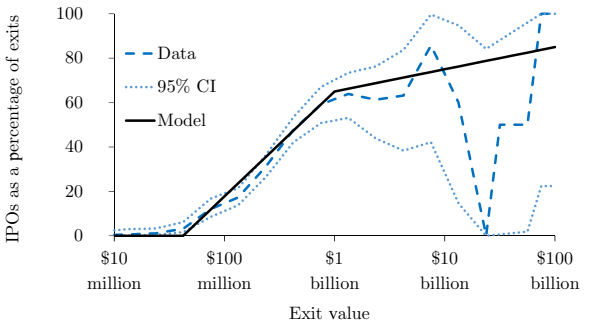

Fig. 3. Probability of an initial public offering (IPO) conditional on exit in VentureSource and model. In the figure, we plot the probability of an IPO exit conditional on exit value. Our model (solid line) is compared with VentureSource data from 2005 to mid-2015 on the exits of VC-backed companies. We group companies into buckets with log-10-width of 0.25, for example \$10 million–\$17 million and \$17 million–\$31 million, and plot the resulting probability estimates (dashed line) and their 95% confidence interval (CI; dotted lines).

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 Fig. 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 after 2013, we censor these companies' exits. 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 Fig. 3, we look at IPO and M&A exits reported in VentureSource for the 2007–2016 period.[20] 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 Fig. 3 show that M&A exits are frequent even among the largest companies. In fact, 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:

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

These estimates allow for very large M&A exits. However, very large M&A deals are far from unknown in the technology and the biotech and pharmaceutical spaces; for example, Vodafone's \$172 billion purchase of Mannesmann in 1999, AOL's \$165 billion purchase of Time Warner in 2000, and Pfizer's \$160 billion merger with Allergan in 2015. Also, 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. However, 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 US 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).

[20] 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 to plot exit rates 20 years out, exit rates in the more recent sample are not significantly different.

3.1. Legal filings and data sets

Our main source of financial structure information is corporate legal filings. A certificate of incorporation 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 et al. (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 restated 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 the paths of their fund raising. For example, we have 20 COIs for Uber.

COIs are complicated legal documents, and different terms can be described in a large variety of ways, often in a 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. We and at least one lawyer (two in most cases and three in more complicated cases) analyzed all COIs.

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.[21] In a number of cases, we consulted media reports and the COIs themselves to reconcile differences between our data sources.

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 collected 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 on fast-growing companies, we restrict our analysis to companies founded after 1994 with a VC round after 2004 and before February 1, 2017. We further limit ourselves to US 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.[22] This analysis yielded more than four hundred companies. For each company, we gathered its financing history across databases and confirmed that it had a VC round with a post-money valuation over $1 billion after 2004 and before February 1, 2017, was based in the U.S, and was founded after 1994. In total, 147 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 147 unicorns, we exclude the five that are set up as limited liability companies (LLCs), as they are not required to file the detailed COIs we get capital structure data from. We exclude another seven companies whose COIs omit 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 B 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 is 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 12 unicorns we excluded are similar along many dimensions. In both the main sample and the set of unicorns with incomplete COI, the average unicorn was founded in 2007 in California, raised seven rounds of funding, and most recently raised a round of about $250 million in 2014 at a post-money valuation of around $3 billion. The small sample of LLCs is slightly older, is smaller, and has raised fewer financing rounds. Of the 135 companies in our sample, 84 are still private as of February 1, 2018, 12 were acquired, 35 went public, and four failed (Better Place, Jawbone, NJOY, and Solyndra). These proportions are broadly similar to the 12 excluded unicorns.

3.3. Financial structure and cash flow terms

COIs list the main contractual relations between classes of shareholders. COIs provide detailed descriptions of

[21] Numerous inconsistencies exist between these data sources. 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 were accessed on February 21, 2017. Round dates also vary considerably between data sources, depending on whether the data provider uses the date the deal was closed, the date the deal was announced, or the date the relevant COI was filed.

[22] 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.

Table 3
Sample of unicorns.
This table provides summary statistics for past and present US unicorns founded after 1994 with a venture capital round after 2004. We compare this with our main sample of unicorns for which we have contractual data. COI = certificates of incorporation.

Sample	All unicorns	Main sample	Limited liability companies	Companies with incomplete COI
Count	147	135	5	7
Most recent unicorn round				
Date	2014.8	2014.9	2013.5	2014.3
Post-money valuation ($m)	3292	3317	1070	4393
Round size ($m)	256	263	121	218
Number of previous equity rounds	5.5	5.6	2.0	6.3
Equity previously raised ($m)	314	319	72	394
Number of COIs we have	11.5	11.8	1.6	13.1
Founded	2007.6	2007.7	2004.0	2007.8
Based in California	66%	68%	20%	57%
Status (as of February 1, 2018)				
Private	92	84	3	5
Went public	37	35	1	1
Acquired	14	12	1	1
Failed	4	4	0	0

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 COIs use intricate and nonstandard 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.

COIs also report the number of shares of each type that the company is authorized to issue. The authorized number is the maximum number of shares the company can issue in each class and not all of these 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.

We use the size of the most recent round in data-sets 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. 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.[23] We make this correction only for the most recent round because COIs subsequent to a financing round generally reduce the authorized preferred share number to match the number issued.

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 Eq. (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 stock option plans of companies (COIs and all available data-sets 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.[24] 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 decreases 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

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

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

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. Major protections are as discussed in Section 2.2 and are the protections given letter codes in the "Code" column. IPO = initial public offering; PMV = post-money valuation; Q_1 = 25th percentile; Q_3 = 75th percentile.

	Code	Count	Mean	Q_1	Median	Q_3
Number of unicorns		135				
Preferences given to latest investors						
Percent of shares new investors senior to			0.64	0.46	0.60	0.87
Senior to some investors		64	0.48			
Senior to all investors	s	41	0.30			
Liquidation multiple > 1	m	9	0.07			
Participation	p	16	0.12			
Cumulative dividends	d	9	0.07			
For those, level			0.07	0.06	0.08	0.08
IPO ratchet	r	20	0.15			
For those, level			1.15	1.00	1.00	1.33
Any major protection		75	0.56			
Preferences given to at least one Investor						
Seniority	s	64	0.47			
Liquidation multiple > 1	m	21	0.16			
Participation	p	27	0.20			
Cumulative dividends	d	14	0.10			
For those, level			0.08	0.06	0.08	0.08
IPO ratchet	r	23	0.17			
For those, level			1.32	1.00	1.25	1.63
Any major protection		92	0.68			
Automatic conversion exemptions						
Any exemption		92	0.68			
For those, valuation needed ($m)			912	200	400	1,225
For those, valuation / PMV			0.53	0.11	0.25	0.87
Require valuation		37	0.27			
For those, valuation needed ($m)			1806	750	1590	2235
For those, valuation / PMV			1.06	0.57	1.00	1.50
Require proceeds		90	0.67			
For those, proceeds needed ($m)			87	50	50	100
For those, proceeds / PMV			0.05	0.03	0.04	0.06
Exemption binds in < 0.5X IPOs	o	32	0.24			

unicorn funding round (as of February 1, 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).

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.[25] However, in 64 out of 135 unicorns, new investors are also senior to some existing preferred shareholders. Moreover, in 41 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 nine unicorns and participation in 16. IPO ratchets are given to the most recent investors in 20 unicorns, typically with a 1X ratchet.[26]

Enforceable automatic conversion exemptions were given out by 92 out of 135 unicorns.[27] Among these 92 unicorns, the average exemption covers all IPOs with exit value below 53% of the post-money valuation and the median exemption covers IPOs below 25% of the post-money

[25] 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.

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

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

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. Q_1 denotes the 25th percentile and Q_3 denotes the 75th percentile.

	Return to most recent round				Return to common shares			
	Mean	Q_1	Median	Q_3	Mean	Q_1	Median	Q_3
Exit through merger or acquisition								
50% below PMV	6%	0%	0%	0%	−63%	−65%	−58%	−55%
75% below PMV	−1%	0%	0%	0%	−91%	−100%	−92%	−84%
90% below PMV	−33%	−53%	−37%	−6%	−100%	−100%	−100%	−100%
Exit through initial public offering								
50% below PMV	−26%	−50%	−46%	0%	−56%	−59%	−50%	−50%
75% below PMV	−39%	−75%	−71%	0%	−83%	−93%	−76%	−75%
90% below PMV	−56%	−90%	−63%	−28%	−96%	−100%	−100%	−90%

valuation. In 90, 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 with the post-money valuation, averaging 5% of post-money valuation. However, IPO proceeds are generally much less than the valuation at the IPO. If a unicorn with a $1 billion post-money valuation gives an automatic conversion exemption in IPOs with proceeds below $200 million and IPO proceeds are equal to 25% of the pre-IPO valuation, that company cannot go public if its pre-IPO value is less than $800 million or 0.8X.

A new investor has a major protection if it has at least one of the following terms: a liquidation multiple greater than one, 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. 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 nine unicorns feature a liquidation multiple above 1X in the most recent round, 21 feature these high liquidation multiples for at least one investor. Only 16 gave their most recent investors participation, but 27 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 92, over 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 investors in that round get 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 44% of their investment in a down-IPO at 10% of the share price they invested at. In less severe down-IPOs, the investors in 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 46% 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 one. 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 when preferred shares recover their original investment must be down-exits when common shares suffer losses relative to the post-money valuation. For example, for the median unicorn, in an M&A exit which is 75% below the most recent round's post-money valuation, the most recent preferred shareholders receive their investment back while each common share receives 92% less than that per share. This pattern repeats across down-M&A exits, with common shares suffering large losses. In down-IPOs, automatic conversion terms mean the per share payouts are often equal.

4.2. Post-money valuations overstate true values for all unicorns

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),

Table 6
Summary of unicorns' fair values (FV) and post-money valuations (PMV).
This table summarizes the post-money valuation, fair value, 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. SD = standard deviation; Q_1 = 25th percentile; Q_3 = 75th percentile.

	Count	Mean	SD	Q_1	Median	Q_3
PMV ($m)	135	3317	6916	1100	1530	2625
FV ($m)	135	2590	6155	785	1020	1802
Δ_V	135	48%	36%	25%	37%	59%
Δ_C	135	56%	49%	23%	41%	71%

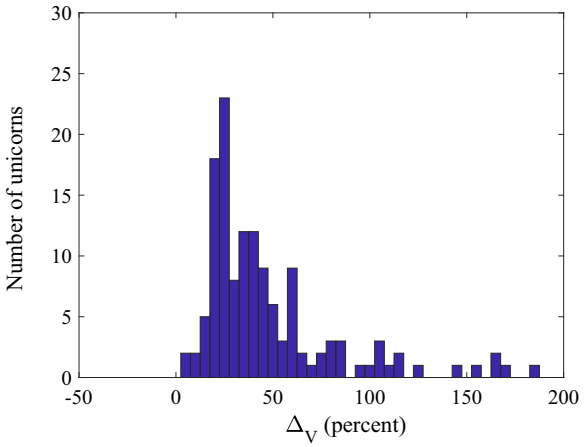

Fig. 4. Distribution of unicorn overvaluation. This figure shows the distribution of overvaluation of the total value, Δ_V, for the unicorns in our main sample. Δ_V is the percentage that the post-money valuation overstates the company's fair value. Unicorn capital structures are reconstructed from certificates of incorporation using the method in Section 3.3 and fair values are calculated using the model in Section 2.

and the corresponding average (median) fair value is only $2.6 billion ($1.0 billion). The average (median) unicorn is overvalued by 48% (37%). Common shares are even more overvalued, with an average (median) overvaluation of 56% (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 Fig. 4, there is a large distribution in overvaluation, with many unicorns only slightly overvalued and 14 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 in which the most recent preferred shareholders have stronger rights are overvalued the most.

For example, in August 2014, JustFab offered Series E investors an IPO ratchet, participation, and seniority, which resulted in an overvaluation of 115%, with the company's fair value being $489 million versus the reported post-money valuation of $1.05 billion. Datto offered its Series B investors in November 2015 an IPO ratchet, cumulative dividends, and a time-varying guaranteed M&A return of up to 41%, resulting in an overvaluation of 124%. Better Place offered investors cumulative dividends, the ability to obstruct down-IPOs, and seniority, resulting in a 113% overvaluation and a 159% 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 December 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 post-money valuation by 25%. Jawbone and NJOY (both now failed) offered investors clauses with similar effects.

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. Uber's overvaluation is thus 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 subsection, we examine how overvaluation is impacted by different assumptions. We examine both our capital structure and contracting assumptions (Section 4.3.1) and our model parameter assumptions (Section 4.3.2). Table 8 shows how overvaluation changes in the different scenarios that we consider. Throughout this subsection, 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 subsection, we test how changing these assumptions impacts valuation.

Valuation errors. Because companies authorize more shares than they have issued, we use post-money valuations to calculate the total number of shares. We gather these valuations from multiple commercial data sets and cross-check their accuracy with press releases and news articles. Despite this, some post-money valuations could be misreported. Inaccurate post-money valuations have a large impact on fair values but a relatively small impact on the extent of overvaluations. If post-money valuations are inflated, the fair values are inflated by roughly the same amount and, as shown in Table 8, overvaluations change only slightly. For example, if the true post-money

Table 7
Detailed unicorns' fair values(FV) and post-money valuations (PMV).
This table presents company-level post-money valuation, fair value, overvaluation of the valuation (Δ_V), and overvaluation of the common share price (Δ_C) for both our main sample of 135 unicorns and the 7 unicorns with incomplete certificates of incorporation. We consider the most recent unicorn financing round before February 1, 2017. The "Status" column reports whether the company underwent an initial public offering ("IPO"), was acquired ("Acq"), closed ("Cls"), or is no longer a unicorn due to a down round ("Dwn") as of February 1, 2018 and is blank if the company remains private. The "Date" column lists the round date. The "Special terms" column lists the major protections given to the most recent round ("Last round") or in any round ("Any round") 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 (COI) 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	Date	PMV	FV	Δ_V	Δ_C	Last round	Any round
23andMe		Jul 15	1.1	0.8	40%	41%	s	s
Actifio		Mar 14	1.1	0.7	65%	79%	mr	
Adaptive Biotech		May 15	1.0	0.8	26%	30%	s	s
Age of Learning		Mar 15	1.0	0.7	41%	43%	s	
Airbnb		Sep 16	31.0	27.0	15%	10%		
Anaplan		Jan 16	1.1	0.9	23%	22%		
AppDirect		Oct 15	1.4	0.9	46%	49%	s	s
AppDynamics	Acq	Dec 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		COI omits necessary information			
Avant		Oct 15	2.0	1.6	24%	29%		
Better Place	Cls	Nov 11	2.3	1.1	113%	159%	dos	dos
Bloom Energy		May 13	3.0	2.6	14%	12%		m
Blue Apron	IPO	Jun 15	2.1	1.6	37%	33%	s	s
Box	IPO	Jul 14	2.6	1.0	161%	204%	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	May 14	4.1	3.5	19%	16%		
CloudFlare		Sep 15	1.8	1.0	83%	85%	os	os
Compass		Aug 16	1.0	0.8	18%	17%		
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	Acq	Nov 15	1.0	0.4	124%	140%	dr	dr
Deem		Jul 14	1.4	1.0	37%	34%		s
Delphix		Jul 15	1.0	0.7	48%	47%	s	s
Demand Media	IPO	Mar 08	1.2	0.6	100%	141%	dos	dos
Denali Therap.	IPO	Jun 16	1.1	0.9	23%	23%	d	d
Docker		Nov 15	1.1	0.9	26%	25%		
DocuSign		Oct 15	3.0	2.3	31%	30%	p	p
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.		Aug 14	1.2	0.6	106%	200%	dps	dps
Eventbrite		Mar 14	1.2	0.9	27%	25%		s
Evernote		May 15	1.7	1.1	54%	57%	o	dop
Fab.com	Acq	Aug 13	1.2	1.0	19%	20%		
Facebook	IPO	May 09	10.0	8.2	22%	18%		
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	IPO	Jan 16	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%		
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		Jun 14	2.3	1.8	27%	23%		
Human Longevity		Apr 16	1.2	1.0	21%	21%		
Illumio		Apr 15	1.0	0.8	30%	28%		
Insidesales.com		Jan 17	1.7	1.4	25%	23%		

(*continued on next page*)

Table 7 (*continued*)

Company	Status	Date	Valuation ($b)		Overvaluation		Special terms	
			PMV	FV	Δ_V	Δ_C	Last round	Any round
Instacart		Dec 14	2.0	1.6	23%	21%		
Intarcia Therap.		Sep 16	3.7	2.8	32%	33%	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	Cls	Jan 16	1.5	1.1	35%	65%		mps
Jet.com	Acq	Nov 15	1.6	1.1	38%	47%	o	do
JetSmarter		Dec 16	1.6	1.1	52%	50%		
JustFab		Aug 14	1.1	0.5	115%	194%	prs	mprs
Kabam	Acq	Aug 14	1.0	0.6	61%	73%	os	os
Kabbage		Oct 15	1.0	0.6	61%	72%	ds	ds
LendingClub	IPO	Apr 14	3.7	2.5	50%	46%	p	p
LifeLock	IPO	Mar 12	1.0	0.7	39%	71%	mr	mprs
LinkedIn	IPO	Oct 08	1.0	0.6	59%	59%	o	o
LivingSocial	Acq	Feb 13	1.5		COI omits necessary information			
Lookout		Feb 15	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%		
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%	80%	os	mos
Moderna		Sep 16	4.7	3.9	22%	19%	s	ds
MongoDB	IPO	Jan 15	1.8	1.5	24%	22%		
Mozido		Oct 14	2.4		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		Feb 14	1.1	0.9	25%	23%		
NJOY	Cls	Feb 14	1.0	0.8	22%	21%		s
Nutanix	IPO	Aug 14	2.0	0.8	155%	199%	rs	mrs
OfferUp		Nov 16	1.3	0.9	38%	38%	s	s
Okta	IPO	Sep 15	1.2	1.0	25%	23%		
OnDeck	IPO	Mar 14	1.0	0.5	107%	123%	dos	dops
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	Dwn	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	Aug 14	3.6	3.0	22%	18%		
Qualtrics		Sep 14	1.0	0.8	32%	78%	opr	oprs
Quanergy Syst.		Aug 16	1.6	0.9	85%	85%	os	os
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	Cls	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	May 15	6.0	2.3	165%	171%	rs	rs
Stemcentrx	Acq	Sep 15	5.0	4.2	18%	15%		r
Stripe		Nov 16	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	Dwn	Aug 15	1.7	1.2	40%	42%	r	mr
Theranos		Feb 14	9.1	6.7	36%	32%	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

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Table 7 (*continued*)

Company	Status	Date	Valuation ($b)		Overvaluation		Special terms	
			PMV	FV	Δ_V	Δ_C	Last round	Any round
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	188%	196%	dms	dms
Violin Memory	IPO	Feb 13	1.1	0.8	37%	42%	ms	ms
Vox Media		Aug 15	1.1	0.8	29%	36%	p	p
Warby Parker		Apr 15	1.2	1.0	25%	23%		
Wayfair	IPO	Mar 14	2.0	1.1	86%	114%	op	op
WeWork		Oct 16	16.9	14.2	19%	14%		s
WhatsApp	Acq	Jul 13	1.6	1.0	60%	58%	p	p
Wish		May 15	3.5		COI omits necessary information			
Workday	IPO	Mar 12	2.7	1.8	48%	45%	s	ps
Zenefits		May 15	4.5	3.7	20%	17%		
ZenPayroll		Jun 16	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	12.0		COI omits necessary information			

Table 8
Overvaluation under robustness checks.
This table 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 Subsection 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 rate of 2.5%, and exits at a Poisson rate $\lambda = 0.25$. PMV = post-money valuation; IPO = initial public offering; SD = standard deviation; Q_1 = 25th percentile; Q_3 = 75th percentile.

	Mean	SD	Q_1	Median	Q_3
Baseline	48%	36%	25%	37%	59%
Real PMV 20% above reported	48%	36%	24%	37%	59%
Real PMV 20% below reported	43%	31%	22%	34%	52%
All authorized preferred issued	49%	37%	25%	37%	57%
Option pool is 0% of PMV	41%	35%	18%	30%	51%
Option pool is 10% of PMV	55%	36%	31%	44%	67%
25% of common are options	50%	36%	27%	40%	61%
50% of common are options	54%	37%	29%	42%	64%
5% leverage	37%	25%	20%	30%	45%
10% leverage	30%	19%	17%	25%	37%
Cram down rounds 10% of the time	40%	27%	22%	32%	50%
Cram down rounds 25% of the time	34%	21%	19%	28%	42%
IPO holdup rights used 50% of the time	43%	35%	23%	33%	45%
IPO holdup rights never exercised	39%	37%	21%	27%	38%
Volatility $\sigma = 0.5$	74%	118%	21%	34%	66%
Volatility $\sigma = 0.7$	57%	56%	25%	38%	65%
Volatility $\sigma = 1.1$	40%	25%	22%	33%	50%
Exit rate $\lambda = 0.5$	63%	64%	25%	41%	74%
Exit rate $\lambda = 0.125$	34%	21%	20%	28%	42%
Exits with values above $1 billion are IPOs	60%	57%	36%	48%	66%
50% of exits are IPOs	48%	33%	24%	38%	61%
Exit type that benefits common	34%	35%	6%	21%	51%
IPO proceeds of $0.1X(T)$	51%	35%	26%	42%	62%
IPO proceeds of $0.5X(T)$	46%	36%	23%	35%	55%
Risk-free rate $r_f = 0\%$	59%	49%	27%	43%	69%
Risk-free rate $r_f = 5\%$	42%	30%	22%	33%	52%
Annual 1% illiquidity premium	45%	33%	23%	35%	55%
Annual 2% illiquidity premium	43%	30%	23%	34%	51%

valuations were all 20% above our recorded numbers, overvaluation stays at 37%. If all of our post-money valuations were 20% below the true post-money valuations, the 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 a larger number of 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, not 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.[28] The S-1 data of now-public unicorns is consistent with unicorns actively issuing options. Square issued 39 million options, implying at least a 10% option pool. As we cannot be sure that 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 40%.

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, combined with the fact that few of them are profitable, 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 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 cram down rounds in which 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.

Holdup 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 that 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 33%.

4.3.2. Model parameter assumptions

Section 2.4 shows how varying parameters impact the results for our simple unicorn example. This subsection repeats that analysis for the main sample of 135 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 per year reduces overvaluation to 33%, decreasing volatility to 0.7 per year increase overvaluation to 38%, 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 41%. Reducing the exit rate to 0.125 reduces the overvaluation to 28%.

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%. 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 benefit common shareholders. Unrealistically, this leads to IPOs in almost all cases and overvaluation falls to 21%.

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

IPO proceeds. Changing the IPO proceeds has a relatively small impact on overvaluation. When we assume that IPO proceeds are 10% of the firm's value immediately before the IPO, overvaluation rises to 42% as fewer automatic conversion terms are triggered. If we assume IPO proceeds are 50% of the IPO amount, overvaluation falls to 35%.

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 43%, and increasing the risk-free rate to 5% decreases overvaluation to 33%.

Illiquidity discount. Investments in private companies are illiquid and could require a return that exceeds the market rate. To test the impact of this assumption, we update the discounted present value of every claim to take into account an annual illiquidity premium of γ.[29]

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

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

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. Essentially no reporting exists on 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 74%.[30] Furthermore, the gain for investors with protections is, as a first approximation, entirely a wealth transfer from other investors.

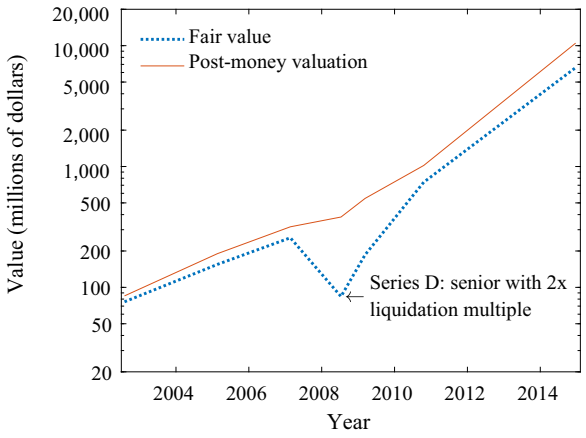

Fig. 5. SpaceX fair value. This figure compares SpaceX's post-money valuation (solid) with the fair value of the company from our model (dotted). The value is reported using a logarithmic scale. SpaceX's capital structure at each round is reconstructed from its certificates of incorporation using the method in Section 3.3 and its fair values are calculated using the model and parameters in Section 2.

The Securities and Exchange Commission (SEC) has similar concerns about unicorn valuations. As Mary Jo White, then 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."[31] 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 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 post-money valuation but did not alter its true value. Fig. 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 suggesting that SpaceX structured these deals to manipulate its valuation. The Series D contractual terms could 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 can use more

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

[30] 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.

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

Table 9
Impact of hypothetical qualified initial public offering (IPO) restrictions on overvaluation.
This table reports the impact of qualified IPO restrictions on the fair values of the largest ten venture capital–backed companies that were private as of February 1, 2018. 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 (COI) 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	
Name	PMV	Date	FV	Δ_V	FV	Δ_V
Uber	68.0	Jun 16	60.6	12%	44.8	52%
Airbnb	31.0	Sep 16	27.0	15%	18.9	64%
Palantir	20.5	Dec 15	17.8	15%	13.0	58%
WeWork	16.9	Oct 16	14.2	19%	10.1	67%
Pinterest	11.4	May 15	9.5	19%	7.0	63%
SpaceX	10.5	Jan 15	6.6	59%	6.3	65%
Dropbox	10.4	Jan 14	8.6	21%	5.7	83%
Theranos	9.1	Feb 14	6.7	36%	3.0	205%
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%		74%

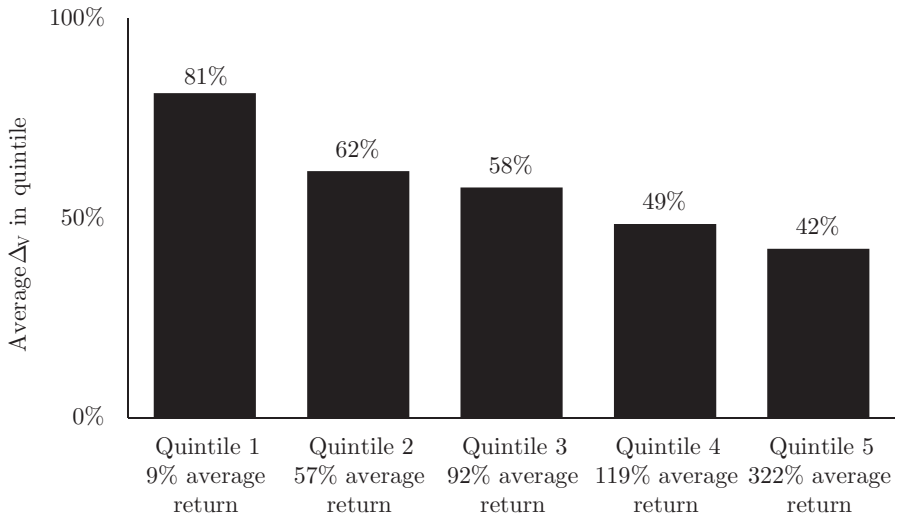

Fig. 6. Overvaluation at different levels of exit performance. This figure shows the relation between overvaluation and exit outcomes for the companies in our unicorn sample that had exited as of February 1, 2018. Companies are divided into five quintiles based on their exit (merger or acquisition price or initial public offering value net of proceeds) relative to the post-money valuation of their latest round. The average overvaluation is reported for each of these quintiles based on unicorn capital structures reconstructed from certificates of incorporation using the method in Section 3.3 and fair values calculated using the model and parameters in Section 2.

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 relation 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, 51 companies exited as of February 1, 2018. 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. We assume M&As of unreported value were not successful. On average, there is an 18 month time gap between the last financing round and the exit. Fig. 6 shows a negative relation between overvaluation and exit outcomes, with outcomes measured as the exit value relative to post-money valuation. The lowest quintile of exit returns has twice the average overvaluation of 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 quartile. A one standard deviation (36%) increase in overvaluation is associated with a 10 percentage point increase in the probability of

Table 10
Relationship between overvaluation and failure.
This table reports the determinants of failure for the venture capital–backed unicorns in our main sample that had exited as of February 1, 2018. We define failure as having an exit in the bottom quartile of exits relative to post-money valuation. This is equivalent to a merger or sale at a value at least 51% below the most recent PMV or an initial public offering with net proceeds value 51% or more below the PMV. Specifications (1) and (2) are under ordinary least squares (OLS). Specifications (3) and (4) are under logit. In all specifications, 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 and two asterisks (**) denotes significance at 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	0.28**	0.26*	1.35*	1.33*
	(0.14)	(0.16)	(0.71)	(0.78)
Log post-money valuation		0.04		0.21
		(0.14)		(0.76)
Log amount raised		−0.03		−0.28
		(0.14)		(0.75)
Time to exit		0.08		0.46
		(0.10)		(0.51)
Market return		−0.06		−0.31
		(0.75)		(3.80)
Year founded		0.00		−0.01
		(0.02)		(0.10)
Based in California		−0.03		−0.24
		(0.15)		(0.84)
Number of observations	51	51	51	51
Adjusted R^2	6%	−4%		
R^2	8%	11%		

an unsuccessful exit, a large increase given only 25% of exits are bottom quartile. This further supports the conjecture that substantial overvaluation could result if the relatively struggling companies try to attract investors by introducing a variety of sweetening contractual terms. These results hold despite a very small sample size and a substantial time gap, 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 would 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. Our model applies the contingent claims option framework to valuing venture-backed companies, following the lead of Metrick and Yasuda (2010b). 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 48%. A large variation exists in the degree of overvaluation. While the ten least overvalued companies are overvalued on average only by 13%, the ten most overvalued companies are on average overvalued by 145%.

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. Similar to how the Novy-Marx and Rauh (2011) analysis of public pension plans quantified a valuation bias that knowledgeable practitioners were aware of but had not focused on, we hope that our analysis of unicorn valuations puts pressure on venture capitalists and mutual funds to more accurately report the values of their holdings. Better reporting would benefit limited partners, employees with stock options, and the entire venture capital ecosystem.

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 foster understanding of 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.

References

Agarwal, V., Barber, B.M., Cheng, S., Hameed, A., Yasuda, A., 2017. Private company valuations by mutual funds. Georgia State University, Atlanta, GA. Unpublished working paper.
Barber, B.M., Yasuda, A., 2017. Interim fund performance and fundraising in private equity. J. Financial Econ. 124 (1), 172–194.
Barth, M.E., 1994. Fair value accounting: evidence from investment securities and the market valuation of banks. Account. Rev. 69 (1), 1–25.
Black, F., Scholes, M., 1973. The pricing of options and corporate liabilities. J. Polit. Econ. 81 (3), 637–654. doi:10.1086/260062.
Bondt, W.F., Thaler, R., 1985. Does the stock market overreact? J. Finance 40 (3), 793–805.
Brown, G.W., Gredil, O.R., Kaplan, S.N., 2019. Do private equity funds manipulate reported returns? J. Financial Econ. 132 (2), 267–297. doi:10.1016/j.jfineco.2018.10.011.
Carroll, T.J., Linsmeier, T.J., Petroni, K.R., 2003. The reliability of fair value versus historical cost information: evidence from closed-end mutual funds. J. Account. Audit. Finance 18 (1), 1–24.
Chakraborty, I., Ewens, M., 2018. Managing performance signals through delay: evidence from venture capital. Manag. Sci. 64 (6), 2875–2900. doi:10.1287/mnsc.2016.2662.

Chernenko, S., Lerner, J., Zeng, Y., 2017. Mutual funds as venture capitalists? Evidence from unicorns. The Ohio State University, Columbus, OH. Unpublished working paper.
Chung, J.-W., Sensoy, B.A., Stern, L., Weisbach, M.S., 2012. Pay for performance from future fund flows: the case of private equity. Rev. Financial Stud. 25 (11), 3259–3304.
Cochrane, J.H., 2005. The risk and return of venture capital. J. Financial Econ. 75 (1), 3–52.
Cumming, D., 2008. Contracts and exits in venture capital finance. Rev. Financial Stud. 21 (5), 1947–1982.
Dechow, P.M., Sloan, R.G., Sweeney, A.P., 1995. Detecting earnings management. Account. Rev. 70 (2), 193–225.
DeFond, M.L., Jiambalvo, J., 1994. Debt covenant violation and manipulation of accruals. J. Account. Econ. 17 (1–2), 145–176.
Ewens, M., 2009. A new model of venture capital risk and return. California Institute of Technology, Pasadena, CA. Unpublished working paper.
French, K.R., Poterba, J.M., 1991. Were Japanese stock prices too high? J. Financial Econ. 29 (2), 337–363.
Gompers, P., Gornall, W., Kaplan, S.N., Strebulaev, I.A., 2019. How do venture capitalists make decisions? J. Financial Econ. https://www.sciencedirect.com/science/article/pii/S0304405X19301680
Gornall, W., Strebulaev, I.A., 2015. The economic impact of venture capital: evidence from public companies. Stanford University, Stanford, CA. Unpublished working paper.
Hackbarth, D., Mauer, D.C., 2011. Optimal priority structure, capital structure, and investment. Rev. Financial Stud. 25 (3), 747–796.
Harris, R.S., Jenkinson, T., Kaplan, S.N., 2014. Private equity performance: what do we know? J. Finance 69 (5), 1851–1882.
Harris, R.S., Jenkinson, T., Kaplan, S.N., 2016. How do private equity investments perform compared to public equity? J. Invest. Manag. 14 (3), 1–24.
Healy, P.M., 1985. The effect of bonus schemes on accounting decisions. J. Account. Econ. 7 (1–3), 85–107.
Hsu, D.H., 2004. What do entrepreneurs pay for venture capital affiliation? J. Finance 59 (4), 1805–1844.
Kaplan, S.N., Schoar, A., 2005. Private equity performance: returns, persistence, and capital flows. J. Finance 60 (4), 1791–1823.
Kaplan, S.N., Strömberg, P., 2003. Financial contracting theory meets the real world: an empirical analysis of venture capital contracts. Rev. Econ. Stud. 70 (2), 281–315.
Kaplan, S.N., Strömberg, P., 2004. Characteristics, contracts, and actions: evidence from venture capitalist analyses. J. Finance 59 (5), 2177–2210.
Korteweg, A., Nagel, S., 2016. Risk-adjusting the returns to venture capital. J. Finance 71 (3), 1437–1470. doi:10.1111/jofi.12390.
Korteweg, A., Sorensen, M., 2010. Risk and return characteristics of venture capital-backed entrepreneurial companies. Rev. Financial Stud. 23 (10), 3738–3772.
Kupiec, P.H., Kah, A., 1999. On the origin and interpretation of OAS. J. Fixed Income 9 (3), 82–92.
Kwon, S., Lowry, M., Qian, Y., 2017. Mutual fund investments in private firms. Drexel University, Philadelphia, PA. Unpublished working paper.
Lamont, O.A., Thaler, R.H., 2003. Can the market add and subtract? Mispricing in tech stock carve-outs. J. Polit. Econ. 111 (2), 227–268.
Litvak, K., 2009. Venture capital limited partnership agreements: understanding compensation arrangements. Univ. Chicago Law Rev. 76 (1), 161–218.
Merton, R.C., 1974. On the pricing of corporate debt: the risk structure of interest rates. J. Finance 29 (2), 449–470.
Metrick, A., Yasuda, A., 2010. The economics of private equity funds. Rev. Financial Stud. 23, 2303–2341.
Metrick, A., Yasuda, A., 2010. Venture Capital and the Finance of Innovation. John Wiley and Sons, Hoboken, NJ.
Novy-Marx, R., Rauh, J., 2011. Public pension promises: how big are they and what are they worth? J. Finance 66 (4), 1211–1249.
Plantin, G., Sapra, H., Shin, H.S., 2008. Marking-to-market: panacea or Pandora's box? J. Account. Res. 46 (2), 435–460.
Ritter, J.R., 1991. The long-run performance of initial public offerings. J. Finance 46 (1), 3–27.
Ritter, J.R., 2015. Growth capital-backed IPOs. Financial Rev. 50 (4), 481–515.
Robinson, D.T., Sensoy, B.A., 2013. Do private equity fund managers earn their fees? Compensation, ownership, and cash flow performance. Rev. Financial Stud. 26 (11), 2760–2797.
Schwert, G.W., 2003. Anomalies and market efficiency vol. 1, 939–974. (chapter 15).
Stroebel, J.C., Taylor, J.B., 2009. Estimated impact of the fed's mortgage-backed securities purchase program. National Bureau of Economic Research, Cambridge, MA. Unpublished working paper.