# Venture Capital Contracts *

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**Abstract**

We develop a dynamic search and matching model to estimate the impact of venture capital (VC) contract terms on start-up outcomes, and the split of value between entrepreneur and investor, in the presence of endogenous selection. Using a new, large data set of first financing rounds of start-up companies, we find an internally optimal equity split between VC and entrepreneur that maximizes the probability of success, consistent with standard double moral hazard theories. However, in virtually all deals, VCs use their bargaining power to receive more equity than is value-maximizing for the start-up. In most cases, participation rights and investor board representation reduce company value, while shifting more value to the investors. Pay-to-play has the opposite effect. Conditioning on the entrepreneur's quality, high quality investors receive more investor friendly terms in equilibrium. But due to the positive impact of VC quality, a better VC still benefits the start-up and the entrepreneur, though not as much as theoretically possible. We conclude with counterfactual exercises that eliminate certain terms, which benefits entrepreneurs but can decrease the number of deals in the market.

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A large body of academic work examines the problem of financial contracting, and frequently uses the context of an entrepreneur negotiating a financing deal with an investor. Start-up firms are key drivers of innovation and employment growth, and the efficient allocation of capital to early stage firms is crucial to their success (Solow, 1957). Financial contracting plays a key role at this stage, as information asymmetries and agency problems are severe (Hall and Lerner, 2010), and the observed contracts between entrepreneurs and venture capitalists (VCs) are quite complex. The predominant explanation in the theoretical literature is that the complicated contractual features, such as convertibility, improve incentives and information sharing (e.g., Cornelli and Yosha, 2003; Kaplan and Strömberg, 2003; Schmidt, 2003; Repullo and Suarez, 2004; Hellmann, 2006). This result is usually derived under the assumption that investors are homogeneous and competitive, and thus earn zero rents.

A contrasting view is that investors negotiate to include certain contract terms not to grow the size of the pie that is divided between the contracting parties, but to change the distribution of the pie in their favor. This is possible because VCs are not homogeneous, as evidenced by the persistence in VC returns (e.g., Kaplan and Schoar, 2005; Hochberg, Ljungqvist, and Vissing-Jorgensen, 2014; Braun, Jenkinson, and Stoff, 2017; Korteweg and Sorensen, 2017), and the positive relation between VC fees and performance (Robinson and Sensoy, 2013). A VC of lesser quality (a short-hand for its experience, network, and other value-added activities) is usually a poor substitute for a greater quality investor (similar to models of economic superstars, such as Rosen, 1981). Moreover, VCs are repeat players in the market for start-up financing, with a more comprehensive view of the market and the distribution of possible outcomes, and a better understanding of the implications of complicated contract terms. As a result, they have substantial bargaining power, while lawyers and regulators do not have strong incentives to correct this imbalance. The resulting contracts are favorable to the VC, even if they reduce the start-up's value. This comes at the expense of the entrepreneur, who experiences poor returns (e.g., Moskowitz and Vissing-Jørgensen, 2002; Hall and Woodward, 2010; Cestone, 2014). As of yet, there is little empirical evidence that quantifies in which direction, let alone how much, various contract terms impact outcomes and the distribution of value. This paper helps fill that gap.

A key empirical problem is that contracts are related to the underlying qualities of the entrepreneur and investor, which are unobserved. To address the resulting omitted variables problem we specify a dynamic search and matching model. In broad strokes, the model works as follows. Penniless entrepreneurs search for investors in their start-ups, and vice versa. When two potential counterparties meet, the investor offers a contract. The entrepreneur has bargaining power due to the possibility of refusing the contract and resuming the search process in the hopes of meeting a higher quality investor. The model allows for the contract to affect outcomes (the size of the pie) and the split between investor and entrepreneur (the split of the pie), and allows for a world with perfectly competitive investors with no bargaining power as a special case. Compared to static matching models, our model is tractable and intuitive despite the addition of dynamics and contracts. Intuitively, the dynamic search feature of the model generates a random component to matches, which helps to identify the impact of contracts on outcomes and value splits, controlling for the qualities of the entrepreneur and the investor.

The second main problem is that start-up contracts are private, and data is difficult to find. To take the model to the data, we collect a new data set that contains over 10,000 first-round VC financings between 2002 and 2015. After applying reasonable data filters, we between 1,695 and 2,581 contracts, depending on the outcome variable. This constitutes the largest set of contracts studied in the literature to date, and includes data on both cash flow and control rights. Nearly all contracts are some form of convertible preferred equity. We focus on the investor's equity share upon conversion, participation rights, pay-to-play, and investor seats on the start-up's board. Participation is a cash flow right that gives the investor a preferred equity payout with an additional common equity claim. In contrast, in a convertible preferred security without participation, the investor must ultimately choose between receiving the preferred payout or converting to common equity (e.g., Hellmann, 2006). Pay-to-play is a term that strips the investor of certain cash flow and/or voting rights if it does not participate in a subsequent round of financing. Board seats are an important control right that gives the VC direct influence over corporate decisions.

We find that contracts materially affect start-up values, with both value increasing and decreasing components. Fixing the quality of investor and entrepreneur, the average start-up's value increases with the investor's equity share up to an ownership stake (upon conversion) of 16%. Any further increase in the VC's share decreases firm value. An internal optimal equity share is consistent with theories of double moral hazard in which both the investor and the entrepreneur need to exert effort for the company to succeed (e.g., Hellmann and Puri, 2002; Schmidt, 2003; Casamatta, 2003; Kaplan and Strömberg, 2004; Inderst and Müller, 2004; Hellmann, 2006). While 16% may appear to be a low stake in the case of common equity contracts, this corresponds to 28% of the average firm's value, due to preferred terms such as liquidation preferences, which shift more value towards the VC. In the data, however, the average deal gives the VC an equity share of 40%, which corresponds to nearly half of the firm's value due to preferred terms and VC board seats. Higher quality investors can bargain for higher ownership stakes (or, equivalently, pay a lower share price for a given invested amount), since they add more value to the firm and it is costly for the entrepreneur to search for another investor. Despite the reduction in firm value that results from a suboptimal equity share (and other contract terms), the VC benefits from a higher expected payoff: the average deal value is only 84% of the value under the value-maximizing contract, but receiving nearly half of this value is more than 28% of the maximal value (these numbers include the effects of other contract terms discussed below).

Other contract terms besides equity share also impact firm value and its distribution among agents. Again fixing the agents' qualities, participation significantly lowers the chance that the venture will succeed, while transferring a larger fraction of its value to the VC. The effects of investor board representation go in the same direction for the average start-up, but are only about a third as strong as participation, and for some deals can raise rather than lower their success probability. Pay-to-play has the opposite effect, increasing value and moving the split in favor of the entrepreneur, and is slightly weaker in magnitude than VC board seats. Although we cannot make statements about the value impact of terms that are always present (for example, liquidation preferences and anti-dilution protection exhibit virtually no variation in the data), we can estimate their joint effect on the value split. Overall, they move the split in favor of the VC. Since these terms are always present and thus not likely to be contentious, their impact on the start-up's value may be positive, in a way that benefits both VCs and entrepreneurs.

The equilibrium contract terms negotiated between investor and entrepreneur depend strongly on their respective qualities, and there are important interactions and trade-offs between cash flow and control rights. Entrepreneurs (VCs) match with a range of VCs (entrepreneurs) between an upper and lower threshold. While these ranges are generally increasing in the entrepreneur's (VC's) quality, endogenous contracting introduces exceptions to this rule, such that positively assortative matching does not necessarily hold in settings with contracts. An entrepreneur who matches with his or her lowest acceptable quality VC negotiates a contract with pay-to-play but no participation or VC board seats, and a low investor equity share. If the same entrepreneur matches with a higher quality VC, the VC's equity share rises, up to a point where the VC has enough bargaining power to negotiate for board seats (consistent with Rosenstein, Bruno, Bygrave, and Taylor, 1993, who find that high-quality VCs are more likely to receive board seats). The board seat causes a drop in firm value, but this is mitigated by the higher quality of the VC (which increases the start-up's value) and a smaller increase in the VCs equity share, leaving the entrepreneur no worse off. If the entrepreneur matches with an even higher quality VC, both pay-to-play and the board seat are dropped, the effects of which largely offset each other. VC board representation comes back in with higher quality VCs, while the investor equity share keeps rising. When entrepreneurs match with the very best VCs they can hope to pair up with, the VC gets both participation and board seats. For these VCs, we find that the investor board representation in fact slightly increases firm value, unlike the negative effect for the average start-up. This result is consistent with Rosenstein, Bruno, Bygrave, and Taylor (1993), who report that start-up CEOs rate VC advice no different from outside board members, except for top VC directors, whose advice is considered to be more valuable.

The model does not identify the mechanisms driving these results, and though it is outside the scope of this paper, we offer the following observations. The increased cash flow rights of the investor with participating preferred stock explains the increase in the fraction of firm value that goes to the investor. The channel through which participation reduces total value is less clear. The traditional view is that participation induces the entrepreneur to exert more effort, but this may be offset by, for example, asset substitution incentives from the debt-like features of participation rights, or preferences for window-dressing that stem from such features (Cornelli and Yosha, 2003). VC board seats can move a higher fraction of value to investors through increased control rights. At the same time, they may reduce overall value by reducing incentives for the entrepreneur to exert effort because they have less ownership and control over key decisions, and are possibly overmonitored (Burkart, Gromb, and Panunzi, 1997, who show that this is particularly pertinent when managerial initiative is important), offsetting value creation effects from improved governance and monitoring. In a large survey by Gompers, Gornall, Kaplan, and Strebulaev (2016), 33% of VCs reported that the board of directors was an important factor contributing to failed investments, slightly higher than the proportion that rates the board as having contributed to success. This explanation is consistent with the observation that VC board seats are not included in every deal. Pay-to-play shifts a higher fraction of value to the entrepreneur, because cash flow and/or control rights are returned to the entrepreneur if the VC chooses not to participate in a subsequent financing round, and may increase firm value due to increased incentives to exert effort on the part of the entrepreneur.

It is important to note that the above results do not imply that a VC investment destroys value *in equilibrium*. An entrepreneur is still better off with a higher quality VC (consistent with Sørensen, 2007). For example, for an entrepreneur at the 90% (99%) quality quantile, moving from the lowest to the highest VC it can match with (with endogenously determined contracts) raises the start-up's value by 30% (79%) and the entrepreneur's value by 5% (32%), even though firm value is not maximized and a larger fraction of it goes to the VC due to a higher equity share, participation and board representation. Also note that even the highest quality VCs still leave almost half of firm value to the entrepreneur, despite their considerable bargaining power.

We explore the effects of eliminating the possibility of using various contractual features implemented by contract terms. If VC-friendly features are removed, counterparties sign contracts that benefit the firm and entrepreneurs, while the effect on the VCs depends on the removed term. However, these effects are modest. Additionally, deals become less frequent. The effects are the most pronounced for better-than-average but not top-quality entrepreneurs, who are able to match with higher-quality VCs (but reject lowest-quality VCs they originally matched with), as some of these investors become excluded from deals with top-quality entrepreneurs who wield increased bargaining power and no longer have to accept participation and investor board seats. In the aggregate, due to higher average firm value but lower matching rates, the value of all deals in the market rises by a modest 0.6%. Finally, we explore the effects of decreasing search frictions in the market. The effect on the value of all deals in the market is negative depends on the size of frictions: for example, if the expected time between encounters is halved (an order of magnitude lower), this value decreases by 2.0% (5.9%). If VCs are able to meet new entrepreneurs more frequently, they wield even more bargaining power and claim a higher fraction of the company, negatively affecting its value. In the aggregate, the tension between lower average firm value and higher matching rates appears to not favor the market.We should note that these effects are all on the intensive margin, because we cannot say what happens on the extensive margin, in terms of how many entrepreneurs and investors would enter or leave the market.

Our paper is related to a few different strands of literature. First, in the empirical literature on selection in venture capital, our paper is related to Sørensen (2007), who estimates the impact of selection (matching) versus entrepreneur and investor characteristics on the firm outcome (specifically, the IPO rate). Sørensen (2007) estimates a static matching model in which the split of total firm value between the entrepreneur and investor is exogenously fixed across matches. Our paper differs in two important ways. First, we model the market for venture capital as a dynamic market, instead of a one-shot market, which is more realistic and more tractable. Second, we allow for the endogenous split of the total firm value between the entrepreneur and investor via negotiated contracts. These modifications affect the estimated impact of selection versus qualities on the firm value, and to characterize the impact of various contract terms on outcomes. Our work is also related to Fox, Hsu, and Yang (2015), who study identification in a one-shot matching model with possibly endogenous terms of trade. Their work is mostly theoretical and their application to venture capital does not include contracts. Outside of VC, Matvos (2013) estimates the impact of contract terms in corporate loans, using a different methodology from ours.

Hagedorn, Law, and Manovskii (2017) estimate a dynamic search-matching model of the labor market based on Shimer and Smith (2000) cited below. Their identification approach is based on the knowledge of the dollar value of contracts (in their setup, one-dimensional wages) between firms and employees, and the relative ranking of employee wages in different firms as they switch jobs. Additionally, wages are assumed to not affect the value of the match. The same approach does not work in the VC market as the dollar impact of various contract terms on the value of the start-up and its split is unknown and has to be estimated, and most entrepreneurs only match with a VC once. As a result, we estimate the model differently, using aggregate data moments.

Second, our paper fits into the empirical literature on VC contracts, surveyed in Da Rin, Hellmann, and Puri (2013). The first paper to study contracts is Kaplan and Strömberg (2003). Based on a sample of 213 investments, they provide evidence that the observed contract terms are consistent with both principal-agent and control-rights theories. Hsu (2004) finds that more reputable VCs invest in start-ups at more investor-friendly terms, consistent with our results. Cumming (2008) uses a sample of 223 investments in European VC-backed start-ups and shows that stronger VC control is associated with lower probability of an IPO, consistent with our results on board seats. Bengtsson and Ravid (2009) find significant regional variation in contracts, which is partially driven by differences in competition among investors. Competition is an important feature of our model, and we explore differences across geographies in our robustness tests. Bengtsson and Bernhardt (2014) show that venture capital firms exhibit "style" in their contracts, recycling them over multiple start-ups. This result is also consistent with investor quality being a primary determinant of contracts, as in our model, given that quality is likely to be highly persistent. Finally, Bengtsson and Sensoy (2011) find that more experienced VCs obtain weaker downside-protecting contractual cash flow rights than less experienced VCs. Their explanation is that experienced VCs have superior abilities and more frequently join the boards of their portfolio companies, but the result is also consistent with more experienced VCs matching with higher quality entrepreneurs. Bengtsson and Sensoy (2011) and Bengtsson and Bernhardt (2014) use data that is incorporated in our data set, but we significantly expand the number of deals with contracts. These papers have 1,534 and 4,561 contracts, respectively, across all stages of financing rounds, whereas we have 5,176 deals with some contract data beyond equity shares on first financing rounds alone before applying filters (across all rounds the data contain over 21,000 contracts).

A recent, complimentary paper by Gornall and Strebulaev (2017) also considers the impact of certain contract terms on valuations, using a contingent claims model in the spirit of Merton (1973). Unlike our paper, they can model terms that are always present and provide valuations in dollars, whereas we can only study indirect sensitivities of valuations to contract terms using success probabilities. However, they cannot determine the impact of control terms (such as board seats) on outcomes, or account for the endogeneity of selection and matching, and the importance of VC and entrepreneur quality and the resulting balance of bargaining powers, on valuations. They also assume that VCs break even, and use a complex option valuation model, which is sensitive, amongst others, to assumptions of a geometric Brownian motion process of the underlying asset, ignoring jumps and time-variation in volatility (Peters, 2017).

The matching model in our paper borrows from the theoretical search-matching literature with endogenous terms of trade. Shimer and Smith (2000) and Smith (2011) establish conditions for the existence of an endogenous matching equilibrium in a continuous-time model with a single class of agents encountering each other. They also provide conditions for positively assortative matching, but they do not hold in our model, and we find mild deviations in our estimations. Adachi (2007) models endogenous matching in the marriage market with two classes of agents and endogenous terms of trade as a discrete-time game and shows that as the frequency of encounters increases, the set of equilibrium matches converges to the set of stable matches in the one-shot problem of matching with contracts of Hatfield and Milgrom (2005). Our model is continuous-time, but the Poisson process for encounters makes it similar to Adachi's model. Inderst and Müller (2004) analyze a two-sided exogenous matching model with endogenous contracts in which the supply of venture capital affects the bargaining power of VCs and entrepreneurs, and we explore differences across time periods in our robustness tests, as well as a state-switching extension to our model.[1] Axelson and Makarov (2018) develop a one-sided sequential search model with endogenous contracts where, unlike in our model, entrepreneurs and investors do not know each other's types and investors can potentially observe entrepreneurs' search histories through a credit registry. They show that credit registries lead to more adverse selection and higher investor rents. Apart from a brief discussion, we leave the extension of our two-sided search-matching model to asymmetric information and information aggregation to future work.

The paper is organized as follows. Section 1 discusses the identification intuition behind our approach. Section 2 introduces the formal model. Section 3 describes our data. Section 4 presents our estimation results, with counterfactuals in section 5. Section 6 discussed robustness and proposes model extensions, and section 7 concludes.

# 1 Identification

To illustrate the identification problem and the source of variation in the data that the model exploits to identify the impact of contracts on outcomes, consider the following example. Entrepreneurs search for an investor to finance their start-up company, while at the same time investors are searching for entrepreneurs to fund. Due to search frictions, potential counterparties encounter each other randomly. Upon meeting, the parties attempt to negotiate a contract that is acceptable to both sides. For the purpose of this example, a contract, $c$, is the share of common equity in the start-up received by the investor. If successful, the value of the start-up is

$$\pi = i \cdot e \cdot \exp\{-2.5 \cdot c\}. \tag{1}$$

[1] The importance of a dynamic link between contracts and deal volumes is also recognized by practitioners. See, for example, the Cooley Venture Financing Report, Q1 2017.

The negative impact of $c$ on the value can be justified by entrepreneurs working less if they retain a smaller share of the start-up (in the estimation, we do not restrict the impact to be negative). Suppose there are three types of investors, characterized by $i = 1, 2, 3$, that an entrepreneur is equally likely to encounter. Similarly, suppose there are three types of entrepreneurs, $e = 1, 2, 3$, that an investor is equally likely to encounter. For example, if an $i = 1$ investor and an $e = 2$ entrepreneur meet and agree on $c = 0.4$, then $\pi = 2 \cdot \exp\{-1\}$, the investor receives shares worth $0.8 \cdot \exp\{-1\}$ and the entrepreneur retains an equity stake worth $1.2 \cdot \exp\{-1\}$.

Let feasible matches be as shown in the table below (these outcomes are presented here as given, but in fact are determined endogenously in the equilibrium of the model for a certain set of parameters). Cells for which a match is feasible, contain the value of the start-up, $\pi$, and contract that is acceptable to both the investor and entrepreneur, $c^*$. Empty cells indicate that no contract is acceptable to both agents, relative to waiting for another counterparty to come along. For example, an $i = 3$ investor will match an with $e = 2$ or $e = 3$ entrepreneur, whoever is encountered first, but not with an $e = 1$ type, because the value of waiting for one of the higher type entrepreneurs is higher than the value that could be received from making this match.

| | | Investor type ($i$) | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Entrepreneur type ($e$) | 3 | | $\pi = 4.39$<br>$c^* = 0.13$ | $\pi = 5.11$<br>$c^* = 0.23$ |
| | 2 | | $\pi = 2.51$<br>$c^* = 0.19$ | $\pi = 2.92$<br>$c^* = 0.29$ |
| | 1 | $\pi = 0.58$<br>$c^* = 0.21$ | $\pi = 0.74$<br>$c^* = 0.4$ | |

If we could collect a data set of $i$, $e$, $c^*$, and $\pi$ for a number of realized matches from this game, then the regression

$$\log \pi = \beta_1 c^* + \beta_2 i + \beta_3 e + \varepsilon, \tag{2}$$

is identified and recovers the true coefficients, $\beta_1 = -2.5$, $\beta_2 = 1$, $\beta_3 = 1$, even though matches and contracts are formed endogenously. In practice, in the VC market the researcher has very limited information about most entrepreneurs and infrequent investors. Suppose $e$ is not observed. The regression using remaining observables,

$$\log \pi = b_1 c^* + b_2 i + \varepsilon, \tag{3}$$

yields the biased estimates $\widehat{b}_1 = -4.16$ and $\widehat{b}_2 = 2.29$. This is an omitted variables problem, as $e$

is in the residual, and is correlated with $c^*$ and $i$. The bias in $\widehat{b}_1$ is negative because higher type entrepreneurs retain a larger share of their companies, so that $e$ and $c^*$ are negatively correlated. The positive bias in $\widehat{b}_2$ is due to the positive correlation between $i$ and $e$, as better investors tend to match with better entrepreneurs. Suppose next that both $i$ and $e$ are not observed. A similar regression then yields an even more biased $\widehat{b}_1 = 2.04$, which can lead the researcher to incorrectly conclude that $c^*$ improves the company's value.

To resolve the endogeneity problem, ideally we would have an instrument or natural experiment that generates variation in $i$ and $c$ that is uncorrelated with $e$, or in $e$ and $c$ that is uncorrelated with $i$, but these are very difficult to find. Another alternative would be to include fixed effects into the regression, which would isolate this variation and identify the model, albeit in a less statistically efficient manner compared to including agents' types, as there are many investors and entrepreneurs of equal type for whom a separate fixed effect has to be estimated. However, almost all entrepreneurs and some investors only participate in a single start-up in our data set.[2]

The final alternative is to exploit the search friction and endogenous match formation. In the example, again suppose $e$ is not observed. Take a given entrepreneur of, say, type $e = 2$. This entrepreneur will match with an investor of type $i = 2$ or $i = 3$, depending on who is encountered first, and sign contract $c^* = 0.19$ or $c^* = 0.29$. A investor of type $i = 2$, in turn, will match with any entrepreneur but only sign contract $c^* = 0.19$ with an entrepreneur of type $e = 2$. Similarly, an investor of type $i = 3$ will match with an entrepreneur of type $e = 2$ or $e = 3$ but only sign contract $c^* = 0.29$ with an entrepreneur of type $e = 2$. Hence, observing $i$ and $c^*$ recovers the entrepreneur's type. Suppose next that both $i$ and $e$ are not observed. Even then, observing only $c^*$ recovers the investor's and entrepreneur's type: for example, $c^* = 0.19$ recovers $i = 2$ and $e = 2$.

In practice, the number of the investor's and entrepreneur's types is large, so there can be situations when different combinations of agents sign the same contract. Additionally, the researcher typically does not have a reliable estimate of the value of the start-up $\pi$[3], but instead observes coarse measures of its success (e.g., whether the start-up underwent an initial public offering). These complications mean that the reverse engineering of individual types and the value for each match has to be done simultaneously from contracts and other measures of success, can be imprecise, and is extremely computationally intensive. Instead of reverse-engineering individual $i$, $e$, and $\pi$ for each match, we therefore take a more feasible approach and recover aggregate distributions of $i$, $e$, and $\pi$ across all agents present in the market. We do so by directly matching the aggregate distributions of outcomes across matches produced by the model with the same distributions in

[2] Looking at multiple investment rounds for the same start-up is also not helpful because the start-up's decision makers and objectives are very different across rounds, implying round-specific fixed effects.

[3] In Section 4, we discuss shortcomings of the "post-money valuation" measure sometimes used for this purpose.

the data. Specifically, we use the method of moments to match theoretical and empirical average $c^*$, its variance, its covariance with the IPO rate, etc. Coming back to the example, only the uniform distribution of both investor's and entrepreneur's types, and $\beta_1 = -2.5$ would achieve the best fit between theoretical and empirical moments of outcomes.[4]

Among multiple ways to model endogenous match formation, we choose the model of dynamic search and matching. As a point of contrast, the prior approach in the literature has relied on static matching models that lack the search feature (Sørensen (2007)). In these models, all agents immediately see everyone else in the sample and, as a result, each investor type matches with one entrepreneur type (and vice versa). In turn, there is not enough exogenous variation to separately identify the impact of each agent's type on the contract, and of each agent's type and the contract on the value. The literature resolves this problem by splitting the sample of matches into subsamples by time and argues that all agents who match in a given subsample immediately see everyone else in the subsample but not across subsamples. To the extent that subsamples are different, each investor type matches with one, but different, entrepreneur type (and vice versa) across subsamples, thus resolving the problem. Since the model of dynamic search and matching generates random encounters for any given agent's type, the necessary exogenous variation naturally arises in it. In turn, we can analyze the entire market at once without arbitrarily splitting it. The final advantage of the dynamic search and matching model is that it is more computationally feasible.[5]

## 2 Model

This section describes the full model, which formalizes the intuition from the previous section. Time is continuous and indexed by $t \geq 0$. There are two populations of agents in the market, one containing a continuum of investors (VCs) and the other a continuum of entrepreneurs. Each investor is characterized by a type $i \in [\underline{i}, \bar{i}]$, distributed according to a c.d.f. $F_i(i)$ with a continuous and positive density. Similarly, each entrepreneur is characterized by a type $e \in [\underline{e}, \bar{e}]$, distributed

[4]For reasons similar to ours, distributions rather than point estimates of agents' qualities have previously been estimated in the mutual funds (e.g., Barras, Scaillet, and Wermers, 2010) and hedge funds (e.g., Buraschi, Kosowski, and Sritrakul, 2014) literature. Additionally, most papers in the empirical auctions literature, starting with Paarsch (1992) and summarized in Paarsch and Hong (2006), focuses on distributions of bidders' qualities, or valuations, to analyze efficiency of the auction format.

[5]Because in static matching models, all agents immediately see everyone else, identification proceeds by comparing matches realized in the sample with all unrealized counterfactual matches. The true parameters of the model are obtained when the set of theoretical matches best approximates the set of realized matches in the sample. In the presence of multiple contract terms, the sheer number of counterfactual matches and contracts in them makes this approach infeasible. In contrast, by letting all agents only know the distribution of counterparties' types and encounter a single agent at a time due to search frictions, the dynamic model of search and matching reduces to a simple comparison of matches realized in the sample with the easily computable agents' continuation values.

according to a c.d.f. $F_e(e)$ with a continuous and positive density. Over time, agents cannot switch populations and their types do not change.

Agents arrive to the market unmatched and search for a suitable partner to form a start-up. Search is exogenous: each investor randomly encounters an entrepreneur from the population of entrepreneurs according to a Poisson process with positive intensity $\lambda_i$.[6] Similarly, each entrepreneur randomly encounters an investor from the population of investors according to a Poisson process with positive intensity $\lambda_e$.[7] Search is costly because agents discount value from potential future encounters at constant rate $r$. Upon an encounter, identities of counterparties are instantly revealed to each other[8], and they may enter contract negotiations.

During negotiations, an investor offers a take-it-or-leave-it contract $c \in C$ to an encountered entrepreneur, where contract space $C$ is a set of all possible combinations of contract terms.[9] If the entrepreneur rejects the offer, the agents separate, receive instantaneous payoffs of zero, and resume their search. In a dynamic model, the ability to walk away from an unfavorable offer thus endogenously gives the entrepreneur a type-specific bargaining power, which the investor can internalize in its take-it-or-leave-it offer. If the entrepreneur accepts the offer, the start-up is formed with the instantaneous expected value of

$$\pi(i, e, c) = g(i, e) \cdot h(c). \tag{4}$$

Importantly, $\pi$ is the expected present value of all future uncertain cash flows generated by the start-up, including the exit value, and is obtained over the course of several years. Hence in contrast to models in which the firm value is certain, the agents cannot simply agree on a firm value-maximizing fixed cash transfer from the entrepreneur to the investor, but instead have to sign a contingent contract. The expected value $\pi$ is affected by types of counterparties as well as the contract they sign through continuous and bounded functions $g(i, e)$ and $h(c)$.[10] The

[6] In the model and estimation, the entrepreneurs we have in mind possess positive-NPV projects and are able to attract at least the lowest-type investor. This rules out the vast majority of entrepreneurial individuals with weak ideas, whom investors encounter often, and only leaves serious entrepreneurs that are quite rare.

[7] These assumptions imply that the likelihood to encounter a counterparty of a certain type is independent from a searching agent's type, and independent across agents.

[8] Chemmanur, Krishnan, and Nandy (2011) and Kerr, Lerner, and Schoar (2014) provide evidence that counterparties acquire much information about each other before financing.

[9] For example, if the counterparties can only negotiate over the fraction of equity that the investor receives, then the contract space is a one-dimensional set of fractions of equity: $C \equiv [0, 1]$. If the counterparties can additionally negotiate over the participation term, then $C \equiv [0, 1] \times \{0, 1\}$: the second dimension of the contract space captures the absence or presence of the participation term.

[10] Note that in equilibrium, $i$, $e$, and $c$ interact in subtler way in terms of their impact on $\pi$ because the optimal contract depends on types of matched agents.

counterparties receive instantaneous expected payoffs

$$\pi_i(i,e,c) = \alpha(c)\cdot\pi(i,e,c), \tag{5}$$

$$\pi_e(i,e,c) = (1-\alpha(c))\cdot\pi(i,e,c), \tag{6}$$

where the continuous function $\alpha(c)\in[0,1]$ is the fraction of the expected start-up value that the investor receives. For example, if the counterparties can only negotiate over the fraction of equity that the investor receives, then $\alpha(c)=c$. If the counterparties can additionally negotiate over other contract terms, $\alpha(c)$ can be different from the fraction of equity that the investor receives.

The equilibrium contract $c^*\equiv c^*(i,e)$ offered by investor $i$ to entrepreneur $e$ solves

$$c^*(i,e) = \underset{c\in C:\pi_e(i,e,c)\geq V_e(e)}{\arg\max}\ \pi_i(i,e,c). \tag{7}$$

Intuitively, the investor offers the contract that maximizes its payoff from the start-up subject to the participation constraint of the entrepreneur, who receives the expected present value $V_e(e)$ if it chooses to walk away. If $\pi_i(i,e,c^*)\geq V_i(i)$, the investor offers $c^*$ and the start-up is formed. Otherwise, the investor does not offer any contract, chooses to walk away, and receives the expected present value $V_i(i)$. Both $V_e(e)$ and $V_i(i)$ are defined below. The counterparties that successfully form a start-up exit the market and are replaced by new unmatched agents in their populations.[11]

All unmatched agents maximize their expected present values, $V_i(i)$ and $V_e(e)$. Let $\mu_i(i)$ be the set of types $e$ of entrepreneurs who are willing to accept offer $c^*(i,e)$ from investor $i$. Similarly, let $\mu_e(e)$ be the set of types $i$ of investors who are willing to offer $c^*(i,e)$ to entrepreneur $e$. Because populations of agents remain stationary over time, the model is stationary, so $V_i(i)$ and $V_e(e)$ do not depend on time $t$. Consider $V_i(i)$. At any time, three mutually exclusive events can happen over the next small interval of time $dt$. First, with probability $\lambda_i dt\int_{e\in\mu_i(i)}dF_e(e)$, investor $i$ can encounter an entrepreneur with type $e\in\mu_i(i)$, who is willing to accept the investor's offer of $c^*(i,e)$. If $\pi_i(i,e,c^*)\geq V_i(i)$, the counterparties form a start-up and exit the market, and the investor exchanges its expected present value $V_i(i)$ for instantaneous payoff $\pi_i(i,e,c^*)$; otherwise the investor resumes its search and retains $V_i(i)$. Second, with probability $\lambda_i dt\left(1-\int_{e\in\mu_i(i)}dF_e(e)\right)$, investor $i$ can encounter an entrepreneur with type $e\notin\mu_i(i)$, who is unwilling to accept the investor's offer. Third, with probability $1-\lambda_i dt$, the investor may not encounter an entrepreneur

[11]This assumption ensures that at any time, populations of unmatched investors and entrepreneurs are characterized by the same density functions. Stationarity of populations implies that since, in equilibrium, measures of encounters by agents from both populations have to be equal, measures of unmatched agents, $m_i$ and $m_e$, have to satisfy $\lambda_i m_i=\lambda_e m_e$. These measures do not play any further role in the model and estimation, and only become relevant again when we examine the present value of all potential deals in the market in Sections 5 and 6.

at all. In the last two cases, the investor resumes its search and retains $V_i(i)$. Similarly, there are three mutually exclusive events that can happen to any entrepreneur $e$ over the next small interval of time $dt$, which shape $V_e(e)$. The following proposition (with proof in Appendix A) formalizes the above intuition and presents compact expressions for the agents' expected present values:

**Proposition 1.** *Expected present values admit a discrete-time representation*

$$V_i(i) = \frac{\lambda_i}{r+\lambda_i} \int_e \max\left\{\mathbf{1}_{e\in\mu_i(i)}\pi_i(i,e,c^*), V_i(i)\right\} dF(e), \tag{8}$$

$$V_e(e) = \frac{\lambda_e}{r+\lambda_e} \int_i \max\left\{\mathbf{1}_{i\in\mu_e(e)}\pi_e(i,e,c^*), V_e(e)\right\} dF(i). \tag{9}$$

Proposition 1 shows that our model is equivalent to a discrete-time model, in which periods $t = 1, 2, ...$ capture the number of potential encounters by a given agent. These periods are of random length with expected length equal to $\frac{1}{\lambda_j}$, $j \in \{i, e\}$, so that next period's payoffs are discounted at $\frac{\lambda_j}{r+\lambda_j}$. The discrete-time representation allows us to use the results of Adachi (2003, 2007) to numerically solve the contraction mapping (8) and (9).

The model described above is quite general. First, it allows but does not restrict both VCs and entrepreneurs to have bargaining power, due to their option to continue the search process. The model includes, as a special case, perfectly competitive investors as typically assumed in the theoretical literature. Investors become more competitive when there are more of them ($\lambda_e$ is higher) and when they are more substitutable ($F_i(i)$ has lower dispersion), reaching perfect competition in the limit. We let our estimates inform us about the split of bargaining power. Second, contract terms impact the expected value of a start-up and its split between counterparties in a flexible reduced-form way, via functions $h(c^*)$ and $\alpha(c^*)$. Since contract terms are generic, they can include the fraction of equity received by the investor, liquidation preferences, the number of investor board seats, and many more. In Section 4, we flexibly parameterize and estimate $h(c^*)$ and $\alpha(c^*)$. Importantly, we do not explicitly model a multitude of mechanisms, through which contracts can impact values. By doing so, we do not commit to a specific microeconomic model that can potentially omit or misspecify the important mechanisms.[12] On the contrary, our findings on which contract terms impact values can inform about which mechanisms considered in the theoretical literature are likely important in practice. Additionally, by considering the impact

[12] For example, Schmidt (2003) and Hellmann (2006) consider several mechanisms that can in principle be used to micro-found our setting, but there is no guarantee that there are no other important mechanisms. Matvos (2013) shows how to micro-found, via a model of covenant contracting, a similar reduced-form impact of covenants on expected outcomes for a firm borrowing from a competitive intermediary. However, for reasons similar to ours, he does not explore the additional detail provided by the microeconomic model in his estimation.

of contracts on expected values and evaluating it from agents' revealed preferences at the time of a start-up formation (agents make rational negotiation decisions to maximize their own payoffs), we avoid the problem of having to derive values of contracts with a multitude of complicated derivative features on an underlying asset. This value is extremely uncertain and most of it is driven by the volatility process of the underlying asset, which is entirely unknown in the VC market.

## 3 Data

We construct the sample from several sources, starting with financing rounds of U.S.-headquartered start-up companies between 2002 and 2015, collected from the Dow Jones VentureSource database. We augment this sample with data from VentureEconomics (a well-known venture capital data source), Pitchbook (a relative newcomer in venture capital data, owned by Morningstar), and Correlation Ventures (a quantitative venture capital fund). These additional data significantly supplement and improve the quality and coverage of financing round and outcome information, such as equity stakes, acquisition prices, and failure dates.

A key advantage of Pitchbook over the other data sets is that it contains contract terms beyond the equity share sold to investors, with reasonable coverage going back as far as 2002. We further supplement this sample with contract terms information collected by VC Experts. Both Pitchbook and VC Experts collect articles of incorporation filings from Delaware and California, and encode key contract terms from the financing rounds described in those documents.[13] We include data from restatements of the articles of incorporation filed after later financing rounds, as supplemental prior-round contract terms can sometimes be identified from such refilings. Appendix B shows an example of a certificate of incorporation with multiple contract terms.

Our empirical model considers the first-time interaction between an entrepreneur and a profit-maximizing investor, as the existence of prior investment rounds or alternative objective functions would significantly complicate the contracting game. To best approximate the model setup in the data, we restrict the sample to a start-up's seed-round or Series A financings in which the lead investor is a venture capital firm. Financings greater than \$100 million are also excluded as they are more likely to involve non-VC-backed start-ups. Other early-stage investors, such as friends and family, angels, or incubators, may have objectives other than profit-maximization. Although

[13]California and Delaware are the preferred choices of states of incorporation. Of all start-ups in VentureSource, at least 86% are incorporated in one of these two states: 65% are headquartered in California (and 90% of those are incorporated in Delaware during our sample period), and 61% of non-California firms are incorporated in Delaware. These numbers are lower bounds due to noise in matching names to articles of incorporation. The sample bias towards companies founded in those two states is therefore limited.

start-ups often raise funds from other investors prior to accepting VC money, such funding is usually small relative to the size of the VC round, and is typically in the form of convertible notes, loans or grants whose terms do not materially affect the VC round contracts. The lead investor is the one who negotiates the contract with the entrepreneur, and is identified by a flag in VentureSource, or if missing, by the largest investor in the round. In the 29% of cases where neither is available, we assume the lead investor is the VC with the most experience measured by the years since first investment at the time of financing. We limit the sample to rounds that involve the sale of common or preferred equity, the predominant form of VC securities. This filter drops the 11% of first financing rounds that involve debt financings such as loans and convertible notes that have no immediate impact on equity stakes, or small financings through accelerators or government grants. Our final filter requires that the outcome variable and the main contract terms of interest (equity share, participation, VC board seats, and pay-to-play) are known for each deal. Section 4.2 explains why we restrict ourselves to these specific contract terms. Our main outcome variable is based on initial public offererings and high-value acquisitions, and is defined precisely below. To leave enough time for IPOs and acquisitions to realize, we only consider financing rounds up to and including 2010, while we collect information on exit events through March of 2018.

## 3.1 Descriptive Statistics

The sample consists of 1,695 first financing rounds. Table II reports summary statistics, and variable definitions are in Table I. Panel A of Table II reveals that at the time of financing, the average (median) start-up is 1.6 years (1.1 years) old, measured from the date of incorporation. Most start-ups are in the information technology industry (46% of firms), followed by healthcare (26%). To help identify the frequency with which investors and entrepreneurs meet, we compute how much time has passed since the lead VC negotiated its prior deal's first financing round. The average (median) time between successfully negotiated first financing rounds for a given lead VC is 0.7 (0.28) years.

In the average (median) round, 1.76 (2) financiers invest \$7.2 million (\$5.2 million) in the firm at a post-money valuation of \$21.2 million (\$13 million). Both amounts are in 2012 dollars. Post-money is the valuation proxy of the start-up after the capital infusion, calculated in a straightforward manner from the investors' equity share.[14] The post-money valuation is usually

[14]The investors' equity share is the share of the company owned by investors upon conversion assuming no future dilution. For example, suppose the VC invests \$2 million by purchasing 1 million convertible preferred shares at \$2 per share, with a 1:1 conversion ratio to common stock. The entrepreneur owns 4 million common shares. VCs calculate the post-money valuation to be \$10 million (5 million shares at \$2 each). The ratio of invested amount to post-money valuation is 20%, which is identical to the ratio of investor shares to total shares upon conversion.

interpreted as the market value of the firm at the time of financing ($\pi$ in the model), but it is calculated under the assumption that the entrepreneur (and any other investors) own the same security as the investor in the current round, and that the investor breaks even (i.e., no VC bargaining power). However, in virtually all cases in our data (96%), the investor receives preferred equity that is convertible into common stock, whereas the entrepreneur retains common equity (see also Gornall and Strebulaev, 2017). Since we are interested in the impact of contract terms on valuation, the post-money valuation would be a poor metric to use; instead, the value of the firm at the time of financing is endogenously generated in the model. Still, post-money valuations are useful to compute the equity share of the company sold to investors from post-money valuation and the total capital invested. One traditional data source used in earlier studies – VentureSource – only contains post-money valuations for 553 deals in our sample period, mostly gathered from IPO filings of successful firms. Our additional data collection efforts provide another 1,142 observations in the raw data (2002–2010 financings), resulting in a more complete and balanced sample. Panel B of Table II shows that the average (median, unreported) share sold is 40% (38.5%), with a standard deviation of 17.5%.

Contract terms beyond the equity share (other than board representation) are not reported in the traditional VC data sets, and the empirical literature on contracts is small. Kaplan and Strömberg (2003) analyze 213 contracts from a proprietary data source. Bengtsson and Sensoy (2011) and Bengtsson and Bernhardt (2014) use the VC Experts data and have 425 and approximately 1,110 first-round contracts, respectively, across all stages of financing rounds. We are the first to add the Pitchbook data, which contributes more deals and spans a longer time series than VC Experts, and we have 1,695 to 2,581 deals (depending on the sample) with some contract data beyond equity shares on first financing rounds alone (across all rounds the data contain over 21,000 contracts). Our estimation uses a subset of financings where all terms are available. We consider two classes of contract terms. The first class involves the cash flow rights of investors. When the start-up is acquired or goes public, the investor can either redeem the preferred security, or convert it into common stock, whichever payoff is higher. In the case of nonconversion, the investor receives a payoff equal to the liquidation preference (or less if funds are insufficient) before common equity receives any payout, similar to a debt security payoff. The liquidation preference is typically equal to the invested amount (referred to as "1X") in first round financings, but in 4% of first rounds the investor receives a higher multiple of invested capital. This provision serves as additional downside protection for the investor, as conversion to common equity is only attractive when the exit valuation is high. Participation is a term used in 51% of contracts, that allows the investor to take its liquidation preference payout, and then convert its shares to common equity and receive its share of the remaining value. This raises the payoff to the investor in all outcome scenarios.

Other contract features available to preferred shareholders that involve cash flow rights include cumulative dividends, which are set at a fixed rate (e.g., 8%) and cumulate from investment to exit (payable only at liquidation). The investor requests this feature in a fifth of cases. Financings without this term typically have non-cumulative dividends that are only paid if the board declares them (which virtually never happens). A rarely used full ratchet anti-dilution rights term in our data (2%) acts as another form of downside protection. A financing with these rights would see the conversion price adjusted in step with any future financings with a share price lower than the current price. Some 12% of financings have entrepreneur-friendly pay-to-play requirements. These terms punish investors that do not reinvest in future financings. Finally, 39% of financings have redemption rights. The latter gives the holder of the security the option to call their capital back from the start-up after 3 to 5 years. If a start-up is unable to meet this call, then the preferred shareholder is typically given additional control or cash flow rights.

The second class of contract terms involves investor control rights over the start-up. We observe one major investor control right: board seats. Both VentureSource and Pitchbook provide information that allows us to identify whether the lead investor had a board seat at the time of the investment. Table II shows that 90% of lead investors in our sample have a board seat at the time of the first investment.

Panel C of Table II summarizes exit outcomes for our estimation sample, tracked until March 2018. The table shows that 4% of start-ups went public via an initial public offering (IPO). Acquisitions are more common at 39%. To treat all firms symmetrically, we set outcomes to zero (i.e., still private) if the exit occurs more than seven years after their first financing. One issue with using acquisitions as a measure of success is that many are hidden failures (e.g., Puri and Zarutskie, 2012). To separate these out, we define our main outcome variable, "IPO or Acq. $> 2X$ capital", as an indicator that equals one if the start-up ultimately had an IPO or was acquired at a reported exit valuation of at least two times total capital raised. By this metric, 13% of firms have a successful exit. Over one third of start-ups (35%) are still private by the end of March 2018. The outcome "Out of business" characterizes whether a start-up shut down or went into bankruptcy. It appears to be low at 13%, however, this excludes the hidden failures in acquisitions, and many firms that are still private are in fact failed firms. The incidence of follow-on financing rounds is an alternative measure of success that we use in the robustness section. Start-ups on a good trajectory towards ultimate success typically need follow-on financing within a year to 18 months of their first financing rounds. Using a two-year cutoff, this variable allows us to extend the sample to include all first financing rounds up to and including 2015, resulting in 2,581 deals. By this definition, 73% of sample firms had a follow-on financing round.

### 3.1.1 Sample Selection

Since contract terms are not always observed, we only exploit a subset of all financings. To gauge if this causes any sample selection concerns, we compare our sample to the sample of all first-round deals over our sample period that do not condition on observing any contract terms. Summary statistics for this broader sample are shown in the sub-panel labeled "All deals 2002–2010" of Table II). Firms in the estimation sample raise capital faster (.69 vs. .85 years), raise more capital ($7.3 million vs. $6.3 million) and have higher post-money valuations ($21.2 million vs. $18.9 million). These differences are expected if the data providers focus their energy on more high-profile startups or investors. Reassuringly, these differences are economically small.

Panel B reveals that our requirement that *all* contract terms be available does not result in major differences in contract usage. Across nearly all terms – with the exception of board seats – the fraction of deals with each contract term is similar in our sample and the full sample. Finally, Panel C shows that the sample of firms with full contract coverage are more successful in terms of IPOs (4% vs. 2%) and fewer failures (13% vs. 17%). However, our main variable "IPO or Acq. > 2X capital" is statistically indistinguishable across the samples.

Any potential bias from sample selection in the results below is unclear, though we should note that similar selection issues also plague prior studies that use investment-level returns or contracts. Given that our data represent the largest set of both valuation and contracts data, any selection issues are likely to be smaller in our sample. Section 6 describes robustness of our results to alternative data filters that relax the requirements on available contract data and allow us to analyze 2,439 deals with the "IPO or Acq. > 2X capital" outcome variable.

# 4 Results

We first consider basic regression estimates and then discuss the search model estimates.

## 4.1 Regression analysis

We first explore the correlation between contract terms and startup outcomes in a regression analysis. Table III presents probit and OLS regressions for three outcomes. The dependent variable in columns 1–4 is the indicator for whether a startup financed between 2002–2010 had an IPO or high-value acquisition within seven years of its first financing. The explanatory variables include various combinations of the four major contract terms, including the squared value of the equity share sold to the investor. All regressions include fixed effects for financing year, start-up founding year, industry and start-up headquarters state. The results reveal a U-shaped relationship between VC equity share and outcomes. This result is counterintuitive as it suggests that a full ownership by either a VC or entrepreneur maximizes the firm value or probability of success, in contrast to the hump-shaped relation and an internal optimal VC equity share predicted by double moral hazard models. Pay-to-play and VC board seats weakly correlate with higher valuations and outcome probabilities, while participation strongly correlates with lower outcomes. The last two columns consider the standard IPO outcome (column 5) and the financing (log) post-money valuation. The correlations are similar, with only a change in statistical significance. Of course, these regressions do not control for selection issues and other omitted variables discussed in Section 1.

## 4.2 Search Model

### 4.2.1 Empirical Implementation

We assume that $F_i(i)$ and $F_e(e)$ are Beta distributions on $[0, 10]$ with parameters $(a_i, b_i)$ and $(a_e, b_e)$, and discretize each of these distributions on a 50 point grid.[15] The Beta distribution is very flexible and can generate hump-shaped, skewed, and even U-shaped distributions. See Appendix C for more detail on the contraction mapping.

We assume that the impact of qualities $i$ and $e$ on firm value is captured by a flexible constant-elasticity-of-substitution (CES) function,

$$g(i, e) = \left(0.5 i^{2\rho} + 0.5 e^{2\rho}\right)^{\frac{1}{\rho}} . \tag{10}$$

In particular, when $\rho \to 0$, the impact of qualities is multiplicative: $g(i, e) = i \cdot e$. When $\rho = 1$, qualities are perfect substitutes. Finally, when $\rho \to -\infty$, qualities are perfect complements. Next, we choose flexible functional forms for the impact of contract terms on firm value and its split,

$$\begin{aligned} h(c^*) &= \exp\left\{\beta_1 c_1^* + \beta_2 c_1^{*2} + \beta'_{3:D+1} c_1^* (1 - c_1^*) c_{2:D}^*\right\}, && (11) \\ 1 - \alpha(c^*) &= (1 - c_1^*) \exp\left\{\gamma_1 (1 - c_1^*) + \gamma'_{2:D} c_1^* (1 - c_1^*) c_{2:D}^*\right\}, && (12) \end{aligned}$$

where $D = \dim\{C\}$ is dimensionality of the contract space. In principle, contact terms entering the functional forms can be generic. However, we pay special attention to the fraction of equity

[15] Such a fine grid proves more than sufficient to adequately approximate continuous distributions. The technical role of the normalization is to allow for a sufficiently wide support of qualities so that tails of the Beta distributions disappear at its boundaries. If the support is too narrow so that the density of qualities is positive at its boundaries, such distribution would be unlikely to be encountered in practice, would indicate that some qualities are not captured by it, and would call for widening of the support. Our results are robust in the presence of wider and slightly narrower supports.

retained by the investor, $c_1^*$[16], because of ample theoretical research on its impact on value and also because it serves as a simple benchmark, against which the impact of other terms on the value split can be compared. We also allow $c_{2:D}^*$ to contain products of any two simple contract terms.

Consider the firm value in equation (11). Theory suggests that there can be an internal optimal equity share retained by the investor if there is a double moral hazard problem that requires both the investor and entrepreneur to expend effort (Hellmann, 2006). The linear and quadratic terms, $\beta_1 c_1^*$ and $\beta_2 c_1^{*2}$, in equation (11) allow for that possibility (but we do not enforce an internal optimum in the estimation, allowing for the possibility of a corner solution). $c_{2:D}^*$ is multiplied by $c_1^*(1 - c_1^*)$, because the impact of other terms vanishes as the investor owns a very large or very small fraction of the company. For example, in the extreme case of 100% equity ownership by the investor, there is no incremental role for participation and board seats terms on the agents' payoffs and hence on their incentives to change the value. Similarly, in the extreme case of zero equity ownership by the investor, additional existing equity-like cash flow terms are irrelevant for the agents' payoffs, and the role of control terms such as board seats is greatly diminished.[17] Finally, the exponential function prevents valuations from being negative.

Turning to the value split in equation (12), in the case of common equity, the value is split simply according to the equity shares of the investor and entrepreneur (that is, $\alpha(c^*) = c_1^*$). The exponential term only appears when there are other contract terms beyond the equity share (when $D > 1$). Similarly to the firm value, $c_{2:D}^*$ is multiplied by $c_1^*(1 - c_1^*)$, because the impact of other terms on the agents' payoffs and hence value split vanishes when the investor owns a very large or very small fraction of the company. Most contract terms are downside protections for the investor, such as participation preference, which allocate more value to the investor relative to common equity. To ensure that the value split remains bounded between zero and one, we define any term that is perceived as entrepreneur-friendly in an inverse manner, so that all $\gamma$ coefficients in equation (12) are less than or equal to zero (but we do not enforce this condition in the estimation and revert signs of entrepreneur-friendly term coefficients to positive in all figures and tables). The functional form of equation (12) then ensures that $\alpha(c^*) \in [c_1^*, 1]$. The intercept, $\gamma_1$, captures the value split effect of any terms that we do not have data on, or that are always present. For example, as shown in Panel B of Table II, liquidation preference is nearly always equal to one in our sample of first-round financings.[18]

[16]In the case of convertible preferred equity, $c_1^*$ is the share after conversion.

[17]One nonequity-like cash flow term that remains relevant in this case is liquidation preference. First-round financings almost always include 1X liquidation preference. Because of the lack of variation in the data, this term is assumed always present in the model and is excluded from $c_{2:D}^*$. Our results remain robust if we use a more flexible multiplication term $c_1^{*\zeta_1}(1 - c_1^*)^{\zeta_2}$ and change $\zeta_1, \zeta_2 > 0$ or if we assume that the impact of board seats does not vanish ($\zeta_1 = 0$) when $c_1^* = 0$. The same applies to the value split equation discussed in the next paragraph.

[18]Liquidation preference is perceived by us as the most important term that is captured by $\gamma_1$. Since, in contrast

Since $\pi$ is not observed, to take the model to the data we add an outcome equation that captures the probability of success (captured by "IPO or Acq. $> 2X$ capital" outcome variable in the main model and by IPO or follow-on financing in robustness checks). We use a probit-type specification and define the latent variable

$$Z(i, e, c^*) = \kappa_0 + \kappa_1 \cdot \pi(i, e, c^*) + \eta, \tag{13}$$

with $\eta \sim \mathcal{N}(0, 1)$. A given start-up is successful if $Z \geq 0$, which happens with probability

$$Pr(Success = 1|i, e, c^*) = \Phi(\kappa_0 + \kappa_1 \cdot \pi(i, e, c^*)), \tag{14}$$

where $\Phi(\cdot)$ is the standard normal cumulative distribution function.

We use GMM with the efficient weighting matrix to estimate the parameters of interest, $\theta = (\lambda_i, \lambda_e, a_i, b_i, a_e, b_e, \rho, \beta, \gamma, \kappa)$. For each $\theta$ and for each combination of VC and entrepreneur quality, the model produces the set of equilibrium contract terms, $c^*(i, e; \theta)$, and the probability of success, $Pr(Success = 1|i, e, c^*; \theta)$. Additionally, for each VC, the model produces the distribution of time since last first-round financing, $\tau$. We compute all first and second moments of these model outcomes, as well all correlations among them, across all potential deals in equilibrium. For contract terms that only take values of zero and one, the second moment of their distribution across deals does not contain additional, compared to the first moment, information about model parameters, so we do not use it in the estimation. We also compute the third moment of the only non-binary contract term, VC equity share. See Appendix D for details on the computation of theoretical moments. We compute the same moments in our final sample and search for $\hat{\theta}$ that minimizes the difference between theoretical and empirical moments.[19] To make estimation of the base model and its extensions feasible, we limit the set of contract terms to the VC equity share and, additionally, two cash flow rights terms and one control rights term with high variation in the data: participation preference, pay-to-play, and the VC board seat. We thus have 24 moments and 24 parameters to estimate.[20] The model is just identified.

to other existing cash flow terms, its impact vanishes when $c_1^* = 1$ but, in fact, is the largest when $c_1^* = 0$, $\gamma_1$ is multiplied by $1 - c_1^*$.

[19]Because the GMM objective function is highly non-convex, we use the genetic algorithm to arrive at the neighborhood of a global minimum, then switch to the simplex search algorithm. We also conduct search from multiple starting points and observe that the genetic algorithm generally arrives at the same neighborhood.

[20]The restriction to the first two moments of model outcomes means that at best, in addition to the VC equity share, we can evaluate the impact of no more than three terms. Table II informs that there is so little variation in the liquidation multiple and full ratchet term that these have to be omitted and are captured by $\gamma_1$. Among the remaining terms, redemption rights are perceived as the least important, despite their frequent occurrence. This term appears only relevant in an ex-ante unlikely case when a VC ends up with a start-up whose performance is average but which is unlikely to exit via an IPO or acquisition. In this case, the VC can trigger its redemption

#### 4.2.2 Estimates

For the "IPO or Acq. $> 2X$ capital" outcome variable, Table IV compares theoretical moments computed at estimated parameter values to empirical moments. Most first and covariance moments are matched well, however second empirical moments of the time between VC deals and VC equity share are somewhat underestimated.[21] While the test of overidentifying restrictions is not possible in a just identified model, the overall fit is, visually, sensible.

The remainder of the section proceeds as follows. First, we describe qualitatively the estimated impact of contract terms on the firm value and its split. Second, we quantify distortions to the firm value, relative to the value-maximizing contract, and to the entrepreneur share of it via terms other than common equity, in deals that can occur in the estimated market equilibrium, paying particular attention to several salient deals. Third, we relate our findings to the existing theoretical literature on contracts in the investor-entrepreneur setting. Fourth, we discuss estimates of encounter frequencies and deal frequencies. Fifth, we derive estimates of the expected present value of all deals in the market and contributions to it by agents of different qualities.

*A. Qualitative impact of contract terms on the firm value and its split.*

Table V shows parameter estimates and their standard errors. First, $\hat{\beta}_1 > 0$ and $\hat{\beta}_2 < 0$ capture the concave impact of the VC equity share on the total value and imply that there is an internal VC equity share, at which the firm value (4) parameterized by (10)–(11) is maximized. We quantify the value-maximizing contract later. Second, $\hat{\beta}_3 < 0$ and $\hat{\gamma}_2 < 0$, and the magnitudes of parameters are large, implying that participation is rather beneficial for VCs but detrimental to the total value. Third, $\hat{\beta}_4 > 0$ and $\hat{\gamma}_3 > 0$ imply that pay-to-play is beneficial for entrepreneurs and the total value. Fourth, $\hat{\beta}_5 < 0$ and $\hat{\gamma}_4 < 0$ imply that in absence of other terms, similarly to participation, VC board seats are beneficial for VCs but detrimental to the total value. Compared to participation, the impacts of pay-to-play and VC board seats are small; in particular, the impact of pay-to-play on the firm value is statistically insignificant. Fifth $\hat{\beta}_5 + \hat{\beta}_7 > 0$ and $\hat{\gamma}_4 + \hat{\gamma}_6 > 0$ imply that in the presence of participation, VC board seats become beneficial for both parties and, in turn, the total value.[22] Finally, even when the contract is common convertible equity,

rights; however, upon this event, often the entrepreneur does not have the liquidity to buy out the VC. And in case the start-up fails, there is nothing to redeem. So the value of redemption rights is likely to be low. Similarly, cumulative dividends only become important on the margin in an unlikely case when a start-up does not fail but remains just solvent. As a result, we also omit these two terms. The inclusion of the fourth moment of the VC equity share to the set of moments allows us to add cumulative dividends to the set of terms; the results of this computationally-intensive extension are very similar to our main model, and cumulative dividends do not appear to impact the firm value and its split in a significant way.

[21] Note that the model can easily match these moments standalone, however the data dictates that other moments receive priority in the GMM objective function.

[22] The alternative interpretation is that the participation term can change with the deal type, so that the change

VCs retain a larger fraction of the firm than the VC equity share alone would suggest, because contract terms that are always present (such as 1X liquidation preference) or unavailable in our data are, on average, VC-friendly, as captured by $\hat{\gamma}_1 < 0$.

*B. Deviations from the value-maximizing contract and common equity-implied value split.*

The estimates of Table V imply that the value-maximizing contract should include an internal VC equity share and pay-to-play only, as these terms can improve the firm value. Indeed, the contract that maximizes (4) is $c^{Max} = (0.162, 0, 1, 0)$ and includes 16.2% of VC equity.[23]

How far away are equilibrium contracts from the value-maximizing contract? Figure 1 shows contracts for all feasible combinations of VC and entrepreneur qualities produced by the model at estimated parameter values. Better VCs tend to match with better entrepreneurs, but this pattern is imperfect. As detailed in the figure, sometimes, VCs that would have been unable to attract the best entrepreneurs in the model with exogenously specified contracts are able to do so in our model by offering them very good terms. More commonly, such VCs match with lower-quality entrepreneurs by offering them the most VC-friendly package of terms.[24] A more detailed analysis of equilibrium contracts reveals that the average VC equity share across all feasible deals is 38.9%. For a given entrepreneur, the worst VCs is willing to match with an offer of entrepreneur-friendly pay-to-play and lower-than-average VC equity share. Better VCs remove pay-to-play from their offer and eventually replace it with moderately VC-friendly board seats. The best VCs have sufficient bargaining power to combine board seats with strongly VC-friendly participation and increase the VC equity share up to 45.7%, which is an unconstrained maximizer of $\pi_i(i, e, c)$. In these deals, the entrepreneur-unfriendly impact of participation is somewhat softened by VC board seats. The distance between equilibrium contracts and $c^{Max}$ thus appears to be large.

To quantify the difference between the equilibrium and maximal total value for any feasible

in the effect of VC board seats in the presence of participation can capture the change in the deal type rather than interaction between terms. We address this concern in robustness checks by conducting our analysis on various subsamples of deals that are more homogeneous.

[23]Note that because we cannot evaluate the impact of terms that are always present, the maximal value is conditional on the presence of these terms. It is not necessarily the first-best value, as we only model the VC-entrepreneur conflict, omitting e.g., the LP-GP conflict within the VC firm.

[24]It is not untypical that the set of equilibrium matches has a rather complex shape. Shimer and Smith (2000) and Smith (2011) show that theoretically more tractable assortative matching only obtains under rather restrictive technical conditions on the agents' payoffs that are generally not satisfied under (10)–(12). Without these conditions, the set of matches may not even be convex. Our model can generate positively assortative matching for sets of parameters that are different from the estimated one. In particular, a few models in robustness checks are estimated to have positively assortative matching. Similarly to us, Hagedorn, Law, and Manovskii (2017) estimate the lack of assortative matching in the labor market setting, in which endogenous wages are assumed to not impact the firm value. Our result is important because it implies that assortative matching also does not generally hold in settings with endogenous value-impacting contracts (and therefore should not be assumed). However, it is somewhat tangential to our main narrative, and is discussed in additional detail in Appendix E.

combination of VC and entrepreneur qualities, in the left panel of Figure 2 we fix parties' qualities, change the VC equity share, participation, pay-to-play, and the VC board seat, and show the ratio of the equilibrium to maximal total value obtained under $c^{Max}$ for combinations of terms that occur in equilibrium. In particular, we focus on two salient contracts: first, the representative contract, in which each term is equal to the sample average of the term, $c^{*,Avg} = (0.396, 1, 0, 1)$; second, the unconstrained contract offered to a given entrepreneur by the best VCs it can attract, $c^{*,Unc} = (0.457, 1, 0, 1)$. Figure 2 shows that $c^{*,Avg}$ achieves 84.0% of the maximal total value, while $c^{*,Unc}$ performs worse and achieves only 77.5% of the maximal value.

Next, we quantify the impact of contract terms on the split of value between VC and entrepreneur. In the right panel of Figure 2, we fix parties' qualities, change the VC equity share, participation, pay-to-play, and the VC board seat, and show the fraction of the total value retained by VCs for combinations of terms that occur in equilibrium. Table V suggests that contract terms that are always present (such as 1X liquidation preference) or unavailable in our data are, on average, VC-friendly, resulting in a larger VC fraction of the firm than the VC equity alone would suggest. In particular, while 16.2% of VC equity in the value-maximizing contract $c^{Max}$ may appear low, this contract, in fact, leaves the VC with 27.8% of the total value. In Appendix G, we use a simple Black-Scholes calibration to show that the 11.8% gap is mainly due to the presence of the 1X liquidation preference in the value-maximizing convertible preferred equity contract, which accounts for approximately 75% of the gap. The presence of participation and the VC board seat further increases the VC fraction of the firm. For example, $c^{*,Avg}$ leaves the VC with 48.4% of the total value, while $c^{*,Unc}$ leaves the VC with 53.1% of the value.

The substantial difference between the VC equity share and the fraction of the firm it retains suggests that the post-money valuation, calculated under the assumption that the VC equity share is the only relevant contract term, is a poor metric to evaluate the firm value. A sensible practical modification is to use the fraction of the firm retained by the VC instead. For example, because the best VCs for a given entrepreneur offer $c^{*,Unc} = (0.457, 1, 0, 1)$, the post-money valuation of the resulting firm, per dollar of capital invested, would be $\$1/0.457 = \$2.19$. In contrast, because the best VCs retain 53.1% of the total value, the modified valuation would instead be $\$1/0.513 = \$1.88$, a 14.1% decrease compared to the post-money valuation. The difference is equal to 18.2% in deals with the representative contract $c^{*,Avg}$. In large first-round financings, the dollar difference between the post-money and modified valuation can thus reach millions of dollars.

In Figure 2, we kept qualities of the VC and entrepreneur fixed to isolate the impact of contract terms. However, in equilibrium, more VC-friendly contracts are offered by higher-quality VCs. While such contracts move the firm away from the maximal value it can achieve for a given combination of parties' qualities, the maximal value itself increases with VC quality. As a result, the entrepreneur is still better off with a higher-quality matched VC. Figure 3 illustrates this intuition. For example, for an entrepreneur at the 90% quality quantile, $e = 7.14$, the set of VC qualities who are willing to match is $\mu_e(e) = [3.88, 5.96]$. Moving from the lowest- to the highest-quality VC this entrepreneur can match with (with endogenously determined contracts) raises the firm value by 29.6% and the entrepreneur's value by 4.7%, even though the firm value is not maximized and a larger fraction of it goes to the highest-quality VC due to a higher equity share, participation and board representation. However in an off-equilibrium scenario, had such an entrepreneur been able to retain the contract it signs with the lowest-quality VC, both the firm and entrepreneur value would have instead been raised by 53.5%. For a high-quality entrepreneur at the 99% quantile, the corresponding changes to the firm and entrepreneur value, and both values assuming the entrepreneur retains its best contract are 78.5%, 31.7%, and 123.1%.

Panel A of Table VI provides the additional detail on the total value and its split across deals completed by bottom 10%, 10–50%, 50–90%, and top 10% of VC and entrepreneur qualities. Deals completed by top-quality VCs (entrepreneurs) are, on average, 17 (66) times larger than deals completed by bottom-quality VCs (entrepreneurs); overall, there is more heterogeneity in the total value as a function of entrepreneur quality than VC quality. The VC share of the total value peaks for top-quality VCs and decreases with entrepreneur quality.

*C. Connection to the theoretical literature.*

Our paper does not explicitly model mechanisms that link contracts to the firm value. By modeling this link in reduced form, our results instead inform about which mechanisms considered in the theoretical contracting literature are likely at work in practice. First, in the VC setting, both parties' effort can be valuable but difficult to verify, setting up a double moral hazard problem (e.g., Inderst and Müller, 2004, Hellmann, 2006), which can be mitigated by an internal VC equity share. The internal optimal VC equity share in $c^{Max}$ aligns with this prediction.

Second, convertible securities or debt-equity mixes have been shown to mitigate inefficiencies related to asset substitution (Green, 1984), exit decisions (Hellmann, 2006), sequential investment (Schmidt, 2003), and sequential investment combined with window dressing (Cornelli and Yosha, 2003). In this literature, the focus is on a competitive investor or on feasibility of optimal contracts that may not necessarily occur in equilibrium. Our results suggest that in the presence of participation (which effectively makes the contract a debt-equity mix), the contract appears less efficient at dealing with the above inefficiencies than a regular convertible equity contract.[25] However, this

[25]This finding is consistent with Cornelli and Yosha (2003), pointing to window dressing as a potential inefficiency. Alternatively, convex incentives provided by participation may force entrepreneurs to gamble for success (e.g., DeMarzo, Livdan, and Tchistyi, 2013, and Makarov and Plantin, 2015) instead of working harder to achieve an IPO or follow-on financing. Gambling can increase the likelihood of a good outcome by increasing the likelihood of high

term can still be offered in equilibrium if it increases the value of VCs with substantial bargaining power, even if it is detrimental to the firm value. At the same time, in the presence of pay-to-play, which affects future investment rounds, the contract appears more efficient at dealing with the inefficiencies related to sequential investment.

Third, while the venture capital literature highlights the value of including control terms into contracts, e.g., via giving power to VCs to replace underperforming founders (Ewens and Marx, 2018), theoretically it is possible for these terms to have drawbacks. For example, firms may face a trade-off between benefits of VC support and costs of VC interference in the presence of costly monitoring (Cestone, 2014). There is some evidence of these drawbacks: e.g., Cumming (2008) associates stronger VC control (captured by board seats) with lower probability of an IPO.[26] Relatedly, in public firms with large institutional investors, who share many control privileges of VCs, investor overmonitoring may kill managerial incentive, reducing the firm value (Burkart, Gromb, and Panunzi, 1997). Simply put, our control term, the VC board seat, cannot be beneficial for all deals, or else it would have always been included. Instead, this term is absent in 11% of deals in our sample. It is clear that VCs benefit from having more control, so it must be entrepreneurs for whom the term may sometimes be detrimental. Indeed, we find that the impact of the VC board seat depends on other terms. When the contract is a regular convertible equity, VC board seats negatively impact the value, possibly because entrepreneurs' incentives are not much distorted by cash flow terms. In this case, costs of VC interference appear to overcome benefits of VC support. However, some VCs may still find such combination of cash flow and control terms profitable in equilibrium. At the same time, when the contract includes VC-friendly participation, VC board seats improve the firm's value. It may be that in this case, VC support and interference are both valuable in the presence of distorted incentives and inefficiencies outlined above.[27]

Finally, cash flow and control terms have been shown to either come together to allocate control to investors with equity-like claims (Berglöf, 1994, Kalay and Zender, 1997, and Biais and Casamatta, 1999) or apart to allocate control to investors with debt-like claims in the presence of costly monitoring (Townsend, 1979, Diamond, 1984, Gale and Hellwig, 1985, and Cestone, 2014). Our equilibrium contracts can include the VC board seat either with or without participation. Across all deals, we have a positive correlation between these two terms. Participating convertible

firm value realizations, yet decrease the firm's expected value.

[26]Recently, practitioners have also become concerned with the possibility that some VC-driven boards can negatively impact the firm value. The data-driven analysis conducted by Correlation Ventures can be found on https://medium.com/correlation-ventures/too-many-vc-cooks-in-the-kitchen-65439f422b8.

[27]As mentioned before, another possibility is that the impact of VC board seats is deal type-dependent. If participation is only offered in certain deal types, in which VC control is valuable, then the estimated positive impact of VC board seats in such deals may be unrelated to the presence of participation per se. We examine this alternative possibility in robustness checks by conducting subsample analyses.

equity, keeping value of the VC fixed, is a flatter, more debt-like security than common convertible equity, so our results yield more support to predictions of the second group of papers.[28]

*D. Frequencies of encounters and matches.*

Returning to coefficient estimates, frequencies of VC and entrepreneur encounters suggest that a VC meets a serious entrepreneur, on average, every $1/\hat{\lambda}_i = 31$ days, while a serious entrepreneur arranges a meeting with a VC, on average, every $1/\hat{\lambda}_e = 47$ days. Panel B of Table VI shows that these frequencies of encounters, combined with less interpretable estimates of quality distributions, result in VCs (entrepreneurs) signing deals, on average, every $1/2.153 = 170$ ($1/1.416 = 258$) days. Lower-quality VCs are the most active: for example, 10–50% of VCs by quality sign a deal, on average, every 138 days, while top 10% sign a deal every 324 days. In contrast, bottom 10% of entrepreneurs by quality rarely sign a deal, while top 10% of entrepreneurs sign a deal, on average, in 112 days.

*E. Analysis of the market size.*

Panel C of Table VI combines our estimates of total values and frequencies of encounters into estimates of the expected present value of all deals in the market (the market size) and its segments. To obtain these, we need to know measures of VCs and entrepreneurs in the market. In equilibrium, measures of encounters by the parties have to be equal: $\lambda_i m_i = \lambda_e m_e$, which gives the estimated ratio of measures of entrepreneurs to VCs as $\widehat{m_e/m_i} = \hat{\lambda}_i/\hat{\lambda}_e$. On a per-VC basis, then, the present value of all deals in the market is the sum, across all $i$ and $e$ with appropriate probability weights, of $V_i(i) + V_e(e) \cdot \widehat{m_e/m_i}$. Panel C of Table VI shows that overall, VCs retain 56.47% of the present value of all deals in the market. Bottom 10% of VCs by quality retain 0.57% of this value, while top 10% retain 11.91%. In contrast, bottom 10% of entrepreneurs by quality only retain 0.09% of the value, while top 10% retain 15.19%. In the next section, we examine the impact of various changes in the contracting environment on these ultimate measures of value in the VC market.

[28]Lastly, it is worth mentioning that our model produces persistent contracts for a given VC: in equilibrium, the VC offers either the most VC-friendly contract to worse entrepreneurs or a set of more entrepreneur-friendly contracts that have very little variation to better entrepreneurs. Bengtsson and Bernhardt (2014) associate persistence of VC contracts with VC-specific style. However, style alone is insufficient to generate persistence when VCs encounter entrepreneurs of varying qualities and both parties have sufficient bargaining power to negotiate contracts. Our model suggests that persistence can at least partly be explained by a market equilibrium, where VCs have most of the bargaining power.

# 5 Counterfactual Analysis

In this section, we examine the effect of a change in various features of the VC market on the deal value, frequency of deals, and the present value of all deals in the market. We focus on the effect of a removal of certain contractual features, seeing as how many of them can benefit VCs at the expense of the total value.[29] Additionally, we examine the effect of lowering search frictions (e.g., via introducing a platform akin to AngelList, where agents can easily find each other).

## 5.1 Contractual Features

The naive approach to examine the effect of a removal of contractual features on deals would be to simply remove a feature across deals, and then re-calculate the total value and its split. This approach is incorrect because it is off-equilibrium: in the new equilibrium, agents would rebalance contract terms that implement the remaining features and match differently. Panel A of Table VII shows the average, across all deals, equilibrium effect of a removal of contractual features on the total value and its split. Here and thereafter, the effect is expressed as the percentage of the estimated average total value across deals. We decompose the aggregate equilibrium effect into two partial effects. The first effect, that of rebalancing, occurs when we allow VCs to rebalance remaining contract terms but constrain them to compensate their counterparties enough to retain them. Thus, matching is unaffected. The first effect alone is still off-equilibrium: some VCs, who suffer a decrease in their expected present value, would have incentives to rematch. However, this effect helps understand the impact of contracts on the firm in autarky, in the absence of market effects. The second effect, that of rematching, occurs when we allow VCs to rebalance remaining contract terms and all agents to match differently.

Panel A of Table VII shows that the average effect of rebalancing on the total value and its split is uniformly negative and small. For example, if contractual features implemented by participation are removed, rebalancing results in a 0.06% decrease in the total value. In the absence of market effects, the VC needs to compensate the entrepreneur as before the removal of features to retain it, but now selects a contract from a narrower contract space. Hence the new contract constrains the VC, resulting in a decrease in both the total value and the VC share of it.

In contrast, the average effect of rematching due to a removal of VC-friendly features is posi-

[29]Note that while our model allows to study the effect of a removal of contract terms, our results should be interpreted as a study of a removal of contractual features implemented by these terms (e.g., "double-dipping", which is implemented by participation but could be implemented differently). If, instead, one simply removes terms but not contractual features, a VC could simply implement a feature differently. Additionally, because we do not explicitly model mechanisms, through which contractual features affect the value, we are unable to examine the effect of including a new feature or a removal of a feature that is always present (e.g., debt-like features captured by 1X liquidation). We can only examine the effect of a removal of those features that vary in the sample.

tive. For example, if contractual features implemented by participation are removed, the aggregate equilibrium effect is a 1.65% increase in the total value, implying that rematching alone is responsible for a 1.71% increase. As for the split of value, the aggregate equilibrium effect is a 0.46% increase (1.20% increase) in the VC's (entrepreneur's) value, implying that rematching alone is responsible for a 0.52% increase (1.20% increase). If contractual features implemented by VC board seats are removed, the effects are more modest, while the aggregate equilibrium efect for the VCs is negative at 0.30%. The effects from a removal of pay-to-play features are negligible.

One explanation of the modest aggregate equilibrium effect is that the market for VC capital exhibits a high degree of contractual completeness, so that removed contractual features are easily replicated by remaining features. An alternative explanation is that deal-specific effects can be different but cancel out in the aggregate effect. A more detailed analysis reveals that if, for example, features implemented by participation are removed, deals done by bottom 10% of entrepreneurs increase in value by 0.61%, while VCs (entrepreneurs) lose 0.15% (gain 0.76%) of their value. The effects in deals done by bottom 10% of VCs as well as top 10% of VCs and entrepreneurs are very similar. The biggest winners appear to be deals done by better-than-average but not top entrepeneurs with qualities in the 50–90% quantile interval: they increase in value by 1.88%, while VCs (entrepeneurs) gain 0.75% (1.12%). Quality-specific effects are more modest (non-existent) if features implemented by VC board seats (pay-to-play) are removed. While some quality-specific effects are stronger than the aggregate effect, they are still small, providing only limited support to the alternative explanation above. It is important to note that because VCs and entrepreneurs of certain qualities lose out following the removal of VC-friendly contractual features (even though the aggregate equilibrium effect for both populations of agents is positive), the market cannot simply self-regulate and remove these features: some agents, including those of high quality, are against such a self-regulation.

Panel B of Table VII shows the effect of a removal of contractual features on deal frequencies. If features implemented by participation are removed, deals, on average, become 2.42% less frequent. A more detailed analysis reveals that this decrease is mainly driven by better-than-average but not top entrepreneurs, who stop matching with worse-than-average but not bottom VC: such entrepreneurs (VCs) match 3.90% (4.71%) less frequently. In contrast, bottom entrepreneurs, match marginally more frequently. There is only a marginal (non-existent) effect on deal frequencies if features implemented by VC board seats (pay-to-play) are removed.

The combined intuition behind the results on VC-friendly features is as follows. The restriction constrains the best overall VCs and leads them to offer terms that are less detrimental to the firm value, decreasing their own value but increasing the value of entrepreneurs who match with them. This results in a higher value of waiting for a good match $V_e(e)$ for these entrepreneurs. Such entrepreneurs thus become more selective, stopping to match with the worst VCs they originally matched with. This leads to a lower value of waiting for a good match $V_i(i)$ for such VCs, who have to match with worse entrepreneurs. The rematching effect snowballs in this manner down the ladder of VC and entrepreneur qualities, resulting in entrepreneurs and firms on the whole benefiting. The biggest winners are better-than-average but not top entrepreneurs, who sign deals with on average much better VCs (although less frequently). The biggest losers are top VCs, who sign worse contracts with same entrepeneurs, and low-quality VCs, who struggle to sign any good deals at all.

Panel C of Table VII combines effects of a removal of contractual features on deal values and frequencies into the effect on the expected present value of all deals in the market (the market size). The effect is expressed as the percentage of the estimated expected present value of all deals. If VC-friendly features are removed, the combined effect of higher deal values and lower deal frequencies is positive. For example, when features implemented by participation are removed, the effect is equal to 0.55%, while VCs (entrepreneurs) on average lose 0.18% (gain 0.73%). A more detailed analysis reveals that high-quality entrepreneurs disproportionately benefit: top 10% of entrepreneurs capture 34.3% of the total entrepreneurial gain in present value, or 63.6% of the total change in the present value of all deals. When instead features implemented by VC board seats are removed the effect is equal to 0.48%, while VCs (entrepreneurs) on average lose 0.33% (gain 0.81%).

Our analysis shows that a removal of VC-friendly features in the contractually complex VC market can lead to modest value creation and decrease the VC value disproportionately less, suggesting that the market may benefit from self-regulation by restricting at least the most VC-friendly features (such as "double-dip" implemented by participation). A caveat is that while we consider a general equilibrium in the VC market, agents can have other options away from the market and can leave, or additional agents can enter in the new equilibrium. Because VC value is relatively unaffected, it is more likely that the combined effect of a removal of VC-friendly features would add more value in newly entering entrepreneurs than lose value in departing VCs.

## 5.2 Search Frictions

In this section, we examine the effect of lowering search frictions (e.g., by introducing an online platform where the parties can easily find each other) on the size of the VC market. Specifically, in separate analyses, we increase both $\lambda_i$ and $\lambda_e$ by a factor of 2, 5, and 10.

Table VIII shows that low frictions decrease the market size. The effect is expressed as the percentage of the estimated expected present value of all deals. A small decrease in frictions ($2X$)

leads to a 2.00% decrease in the expected present value of all deals. Entrepreneurs (VCs) on average lose 4.16% (gain 2.16%). A large decrease in frictions ($10X$) leads to a 5.88% decrease in the present value of deals, while entrepreneurs (VCs) on average lose 11.75% (gain 5.87%).

The intuition behind this result is as follows. The estimated distribution of entrepreneur qualities $F_e(e)$ and the relatively low incidence of VCs encountering serious entrepreneurs (and thus, a low expected discount factor $\frac{\lambda_i}{r+\lambda_i}$ of the next encounter) means that VCs rarely meet a high-quality entrepreneur. A decrease in frictions thus substantially shortens the time between VCs encountering high-quality entrepreneurs. In turn, the VCs benefit from dropping many of their worst-quality matches and waiting less for high-quality entrepreneurs. They offer such entrepreneurs substantially more VC-friendly contracts which are more detrimental to the firm value. This effect is particularly strong for the best overall VCs, who only match with the best overall entrepreneurs. In contrast, the estimated distribution of VC qualities $F_i(i)$ and the relatively high incidence of entrepreneurs encountering VCs means that entrepreneurs meet a high-quality VC rather frequently. A decrease in frictions thus only marginally shortens the time between entrepreneurs encountering high-quality VCs. In turn, entrepreneurs benefit less from dropping their worst-quality matches. Additionally, they lack the ability to offer contracts. At the same time, as described above, entrepreneurs are excluded from their best matches by VCs, ending up with worse deals in the new equilibrium. This effect is particularly strong for better-than-average but not the best entrepreneurs, who are excluded from matches with the best overall VCs. The combined effect of lower deal values and higher deal frequencies can depend on the magnitude of search frictions. However, our analysis shows that when frictions are decreased, the first effect dominates, resulting in a smaller market size.

A caveat is that $\lambda_i$ in our model proxies for both search frictions and arrival of new entrepreneurs to replace the matched ones. If only search frictions change but the arrival rate remains the same, the market size may shrink more than our estimates would suggest. Overall, our results suggest that benefits from low-cost search in the VC market are not obvious. Low search frictions can bring about a less entrepreneur-friendly environment, which can lead to entrepreneurs departing to seek financing elsewhere. Our results thus guard against any immediate action to decrease search frictions in the market.[30]

[30]The exercise in this section is also useful to assess bias from modeling selection via a static matching model with no search frictions. Adachi (2003, 2007) shows that when $\lambda_i$ and $\lambda_e$ are high, our model converges to a static matching model. Direct estimation of the model when $\lambda_i$ and $\lambda_e$ are exogenously set high is difficult: technically, the system of Bellman equations underlying the agent's decisions converges slowly when the expected discount factor of the next encounter is close to one. However, since the value is split very differently between the parties in the low- versus high-friction environment, it is likely that the estimates obtained from the model with low frictions would be very different. This insight underlines the importance of modeling search frictions in the VC market.

## 6 Robustness and Extensions

Our results are robust to various model modifications and extensions. First, we check that our results are robust to alternative definitions of success variables and contract terms. In particular, we are interested in the follow-on financing outcome, because it allows us to expand our number of first-round financings to from 1,695 to 2,581. Panels A and B of Tables A2 and A3 in the appendix show that if we focus on IPO or follow-on financing as the definition of success, moment and parameter estimates are qualitatively unaffected. At the same time, parameter estimates obtained using the follow-on financing success variable are less precise; in particular, the link between the firm value and success is insignificant, which is expected because among 73% of startups that receive follow-on financing, there are likely many firms of low quality. Next, we impose more relaxed assumptions on missing contract terms in the data by imputing missing terms as zeros, provided that term sheets are sufficiently detailed (i.e., contain information about the VC equity fraction and at least one additional term). This modification also allows us to expand our number of first-round financings from 1,695 to 2,439. Panel C of Tables A2 and A3 show that our moment and parameter estimates are qualitatively unaffected.

Second, we check whether our results are driven by mixing together separate markets, which have rather distinct features, such as markets in the IT and Healthcare industry, seed and series A rounds, and time periods before and after the major structural technological change around the release of an Amazon's AWS cloud (Ewens, Nanda, and Rhodes-Kropf, 2018). Panels A and B of Table A4 shows that the parties encounter each other more frequently in the IT industry as compared to the Healthcare industry. Qualities in the Healthcare industry are more complementary, potentially reflecting higher required expertise of VCs in this market. Finally, the participation term in the IT industry is notably more firm value-destroying, potentially because projects in the two markets have a different nature: it is arguably easier to walk away from a project in the IT industry when facing bad incentives created by VC-friendly terms. Panel C of Table A4 shows that the market for series A financings has very similar parameters of interest to the global VC market, supporting the intuition that VC board seats are beneficial in the presence of the participation term and not because this combination of terms is only offered in series A deals. Table A5 shows that the parties encounter each other more frequently after the introduction of Amazon's AWS as compared to the earlier period, reflecting the burgeoning IT startup market. Of additional note is that the average VC quality increases in the latter period, and that the participation term is costlier for the firm. The latter result is likely related to a higher incidence of IT startups in the sample after the introduction of the cloud.[31]

[31] An alternative way to account for the technological change would be to include an additional state that captures

Third, we modify various theoretical assumptions that are not estimated. In particular, we change the discount rate from 10% to 20% to capture that the parties may have higher risk aversion; allow VCs and entrepreneurs to be overconfident; and allow for a match-specific shock to the firm value, so that startups formed by same-quality VCs and entrepreneurs can have different contracts and expected values. Appendix F provides the additional detail on these model extensions, as well as the extension in which capital raised by an entrepreneur is an additional endogenous contract term (due to high computational complexity, this case is not estimated; instead, we conduct informative comparative statics). Table A6 shows that in all cases, our results remain robust.

Two additional extensions are of interest. First, in practice, VCs consider multiple entrepreneurs simultaneously, and entrepreneurs sometimes compare multiple simultaneous offers (competing term sheets) from different VCs. Second, even upon an encounter, the counterparties do not completely observe each other's type, giving rise to asymmetric information concerns. These considerations are important but rather difficult to model in a way that makes the estimation feasible, as they expand the state space of the model into additional dimensions (multiple counterparties' qualities that an agent has to simultaneously consider in the first case, and the true and perceived quality of each agent in the second case). We leave these extensions for future research. Note that in the presence of these considerations, a given combination of counterparties' qualities will no longer always sign the same contract, leading to a higher variance of contract terms across all possible deals and hence a potentially better fit between theoretical and empirical variance moments.

## 7 Conclusion

This paper estimates the impact of venture capital contract terms on start-up outcomes and the split of value between entrepreneur and investor, using a dynamic search and matching model to control for endogenous selection. Based on a new, large data set of first financing rounds, we find that contracts materially affect the value of the firm, as well as its split between entrepreneur and investor. Consistent with double moral hazard problems that are common in the literature, there is an internally optimal split between investor and entrepreneur that maximizes the probability of success. However, in virtually all deals, VCs receive more equity than is value-maximizing for the start-up. All else equal, participation rights and investor board seats reduce company value,

technology level into the model and, additionally to other parameters, estimate or calibrate the frequency of switching technology levels. This approach would result in substantial additional computational complexity. When instead we maintain that the VC market is segmented around the introduction of the cloud, we obtain very similar results between the two subsamples. This finding suggests that the results would also be similar in the more complex model, so that it is not clear if there is a significant benefit to modeling technology levels aside from showing robustness.

while shifting more value to the investors. Pay-to-play has the opposite effect. Conditioning on the entrepreneur's quality, high quality investors receive investor friendly terms, including larger equity shares, board seats and participation, whereas low-quality VCs sign contracts with pay-to-play. Due to the positive impact of VC quality on start-up values, having a higher quality VC still benefits the start-up and the entrepreneur in equilibrium, though not as much as they could in theory. Eliminating terms like participation increases start-up values through rematching, making entrepreneurs better off and leaving all but the highest quality investors marginally worse off, though it is not clear how such regulation could be implemented in practice.

Overall, our results suggest that selection of investors and entrepreneurs into deals is a first-order factor to take into account in both the empirical and theoretical literature on financial contracting.

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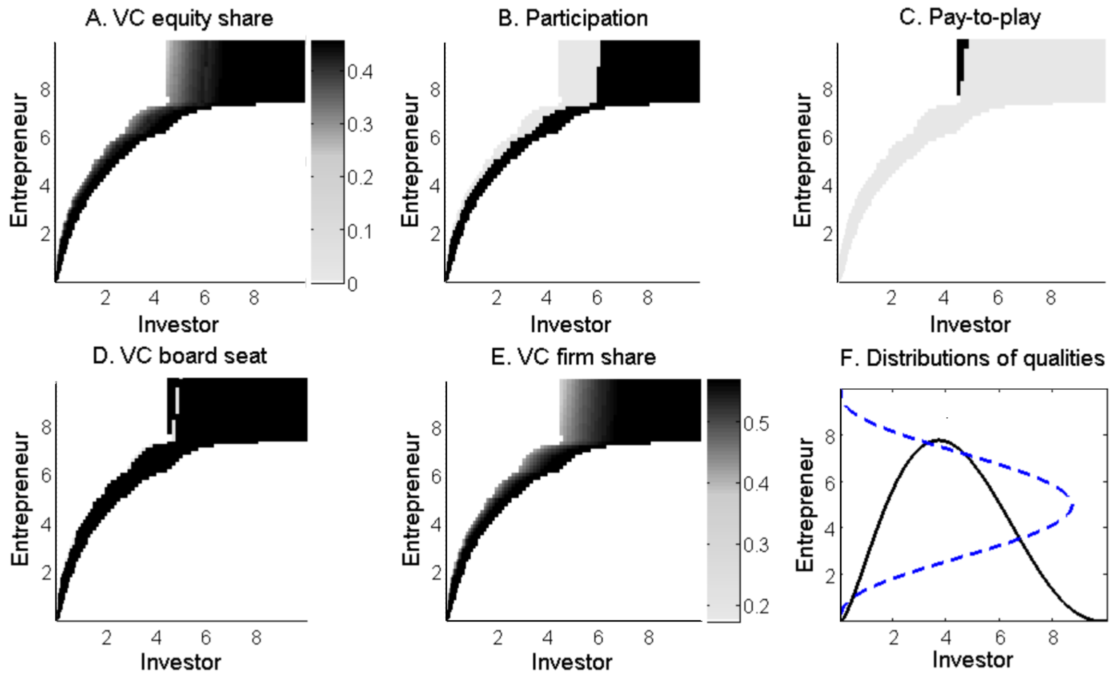


Figure 1: **Equilibrium contract terms for estimated model parameters.** For each combination of VC and entrepreneur quality, Panel A shows the VC equity share, Panel B shows participation, Panel C shows pay-to-play, Panel D shows the VC board seat, and Panel E shows the resulting VC share of the firm. Panel F shows the likelihood of a VC and entrepreneur to be of a certain quality. Combinations of qualities that do not match are shown in white. Combinations of qualities that match but do not include a specified contract term are shown in light grey. The VC equity share and VC share of the firm take values in $[0, 1]$ and are shown in dark greyscale. In particular, the unconstrained VC-optimal contract, $c^{*,Unc} = (0.457, 1, 0, 1)$, includes 45.7% of VC equity and leaves the VC with 53.1% of the firm. Participation, pay-to-play and the VC board seat take values in $\{0, 1\}$, and their inclusion is shown in black.

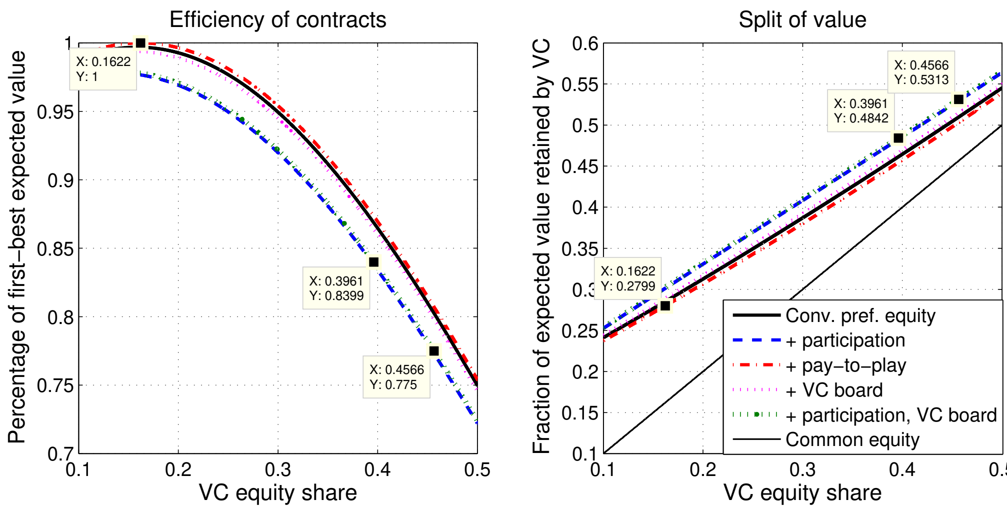


Figure 2: **Impact of contract terms on the total value and its split.** For reasonable values of VC equity share, $c_1 \in [0.1, 0.5]$, and for combinations of participation, pay-to-play, and the VC board seat that occur in equilibrium, Panel A shows the ratio of the total firm value to the maximal value; Panel B shows the fraction of the total value retained by the VC. Qualities of the VC and entrepreneur are kept fixed across contracts. Datatips show the impact of the contract that maximizes the value, $c^{Max} = (0.162, 0, 1, 0)$, the representative contract, $c^{*,Avg} = (0.396, 1, 0, 1)$, and the unconstrained VC-optimal contract, $c^{*,Unc} = (0.457, 1, 0, 1)$, on the total value and its split. These three contracts achieve 100%, 84.0%, and 77.5% of the maximal value and leave the VC with 27.8%, 48.4%, and 53.1% of the firm.

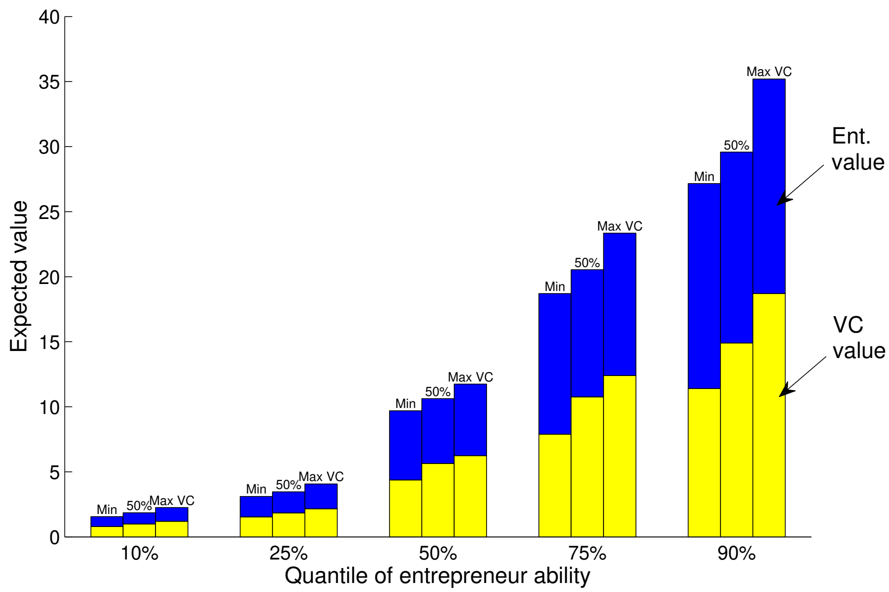


Figure 3: **VC value creation.** For entrepreneurs at the 10%, 25%, 50%, 75%, and 90% quality quantile, and for VCs of the lowest, median, and the highest quality that match with these entrepreneurs in the estimated equilibrium, the figure shows the expected total firm value as well as the fraction of value retained by the VC (light color) and entrepreneur (dark color).

Table I: Variable definitions.

This table shows the definition of variables used throughout the paper.

| Variable | Definition |
|---|---|
| Firm age at financing (yrs) | Years from the start-up's date of incorporation to the date of the first round financing. |
| Information technology | An indicator equal to one if the start-up's industry is information technology. |
| Healthcare | An indicator equal to one if the start-up's industry is healthcare, which include biotechnology. |
| Years since last round (VC) | The number of years since the lead investors last lead investment in a first round financing. |
| Syndicate size | The total number of investors in the first round financing. |
| Capital raised in round (2012 $m) | Total capital raised (in millions of 2012 dollars) in the start-up's first financing rounds (across all investors). |
| Post-money valuation (2012 $m) | The post-money valuation of the first round financing (capital raised plus pre-money valuation, in millions of 2012 dollars). |
| Financing year | The year of the financing. |
| % equity sold to investors | The fraction of equity (as-if-common) sold to investors in the financing round, calculated as the capital raised in the round divided by the post-money valuation. |
| Participating preferred | An indicator variable equal to one if the stock sold in the financing event includes participation (aka "double-dip"). |
| Common stock sold | An indicator variable equal to one if the equity issued in the financing is common stock. |
| Liquidation multiple $>1$ | An indicator variable that is equal to one if the liquidation multiple exceeds 1X. The liquidation multiple provides holders 100% of exit proceeds for sales that are less than $X$ times the original investment amount. |
| Cumulative dividends | An indicator variable equal to one if the stock sold includes cumulative dividends. Such dividends cumulate each year pre-liquidation and are only paid at liquidation. |
| Full ratchet anti-dilution | An indicator variable equal to one if the preferred stock includes full ratchet anti-dilution protection. Such protection results in the original share price to be adjusted 1:1 with any future stock offerings with a lower stock price (through a change in teh conversion price). |
| Pay-to-play | An indicator variable equal to ones if the preferred stock sold includes pay-to-play provisions. These provisions penalize the holder if they fail to reinvest in future financing rounds. |
| Redemption rights | An indicator variable equal to one if the preferred stock sold includes redemption rights. These are types of puts (available after some number of years) that allow the holder to sell back their shares to the start-up at a predetermined price. |
| VC has board seat | An indicator variable equal to one if the VC investor has a board seat at the time of the first financing. |
| IPO | An indicator variable that is equal to one if the start-up had an IPO by the end of 2017Q2. |
| Acquired | An indicator variable that is equal to one if the start-up was acquired the end of 2017Q2. |
| IPO or Acq. $>2X$ capital | An indicator variable that is equal to one if the start-up had an IPO or had an acquisition with a purchase price at least two times capital invested across all its financings by the end of 2017Q2. |
| Out of business | An indicator variable that is equal to one if the start-up had gone out of business by the end of 2017Q2. |
| Still private | An indicator variable that is equal to one if the start-up had not exited by the end of 2017Q2. |
| Seed round | An indicator variable that is equal to one if the first round financing is a Seed round (other rounds as traditional Series A). |

Table II: Summary statistics

Descriptive statistics of start-ups and their first round equity financings for the samples described in section 3. The "IPO/Good acq. sample" includes financing rounds between 2002 and 2010 where the outcome variable is a dummy variable equal to one if the startup had a successful exit by the end of the sample period. A financing is in this sample if the equity stake and contract terms are known. "All deals" are all the financings in 2002–2010 regardless of missing data (e.g. contracts). The variables are as defined in Table I. Only means are reported for indicator variables.

Panel A: Firm and financing characteristics

| | IPO/Good acq. sample | | | | All deals 2002–2010 | | | |
|---|---|---|---|---|---|---|---|---|
| | Obs | Mean | Median | Std dev | Obs | Mean | Median | Std dev |
| Firm age at financing (yrs) | 1,695 | 1.62 | 1.10 | 1.70 | 5,510 | 1.70 | 1.08 | 1.79 |
| Information technology | 1,695 | 0.46 | 0.00 | 0.50 | 5,510 | 0.48 | 0.00 | 0.50 |
| Healthcare | 1,695 | 0.26 | 0.00 | 0.44 | 5,510 | 0.23 | 0.00 | 0.42 |
| Years since last round (VC) | 1,556 | 0.69 | 0.28 | 1.13 | 4,782 | 0.85 | 0.36 | 1.32 |
| Syndicate size | 1,695 | 1.76 | 2.00 | 0.90 | 5,510 | 1.57 | 1.00 | 0.85 |
| Capital raised in round (2012, mil.) | 1,695 | 7.26 | 5.20 | 8.37 | 5,185 | 6.33 | 4.21 | 7.99 |
| Post-money valuation (2012, mil.) | 1,695 | 21.20 | 13.01 | 39.38 | 3,359 | 18.90 | 12.27 | 31.35 |
| Financing year | 1,695 | 2006.33 | 2006.00 | 2.26 | 5,510 | 2006.35 | 2007.00 | 2.40 |
| Seed round | 1,695 | 0.12 | 0.00 | 0.32 | 5,510 | 0.16 | 0.00 | 0.37 |

Panel B: Contracts

| | IPO/Good Acq. sample | | All deals 2002–2010 | |
|---|---|---|---|---|
| | Obs | Mean | Obs | Mean |
| % equity sold to investors | 1,695 | 0.40 | 3,359 | 0.40 |
| Participating pref. | 1,695 | 0.51 | 2,737 | 0.52 |
| Cumulative dividends | 1,694 | 0.21 | 2,702 | 0.22 |
| Pay to play | 1,695 | 0.12 | 2,022 | 0.12 |
| Redemption rights | 1,675 | 0.39 | 2,199 | 0.41 |
| VC has board seat | 1,695 | 0.89 | 5,510 | 0.75 |
| Liquidation mult. $> 1$ | 1,689 | 0.04 | 2,731 | 0.04 |
| Full ratchet | 1,013 | 0.02 | 1,816 | 0.02 |
| Common stock sold? | 1,694 | 0.04 | 2,867 | 0.03 |

Panel C: Outcomes

| | IPO/Good Acq. sample | | All deals 2002–2010 | |
|---|---|---|---|---|
| | Obs | Mean | Obs | Mean |
| Went public | 1,695 | 0.04 | 5,510 | 0.02 |
| Acquired | 1,695 | 0.39 | 5,510 | 0.40 |
| IPO or Acq. $> 2X$ capital | 1,695 | 0.13 | 5,510 | 0.12 |
| Out of business | 1,695 | 0.13 | 5,510 | 0.17 |
| Still private | 1,695 | 0.43 | 5,510 | 0.41 |
| Had follow-on within 2 years | 1,695 | 0.73 | 5,510 | 0.58 |

Table III: Startup outcomes and contract terms

This table reports probit regressions for the indicator for an exit via IPO or high-value acquisition for startups financed between 2002–2010 (columns (1)-(4)). Column (5) presents the same regression (with all controls) for the IPO indicator variable. The final column reports the OLS regression estimates where the dependent variable is the log of the financing post-money valuation (when available) for the sample of startups in columns (4). "% equity sold" is the total (as-if-common) equity stake sold in the start-up's first round financing and "% equity sold$^2$" "Participating pref." is a dummy variable equal to one if the preferred stock sold to investors was participating preferred. "VC has board seat" is equal to one if the lead VC had a board seat at the time of the first financing. "Pay to play" is an indicator variable equal to one if the financing terms include pay-to-play provisions. These provisions require reinvestment by the current investors to maintain their control and/or cash flow rights. "Log Raised" is the log of total capital invested in the financing (2012 dollars). "Year FE" are fixed effects for the financing year. "Year founded FE" are fixed effect for the start-up's founding year. "State FE" are fixed effects for the start-up's state and "Industry FE" are fixed effects for industry. Standard errors reported in parentheses, clustered at the VC firm. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

| | IPO/Good Acq. | | | | IPO | Log post$ |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| % equity sold to investors | -1.589 | -1.741* | -1.561 | -1.641* | -2.367 | -5.004*** |
| | (1.067) | (1.025) | (1.052) | (0.964) | (1.703) | (0.490) |
| % equity sold $^2$ | 2.551** | 2.579** | 2.375** | 2.546** | 4.076*** | 5.252*** |
| | (1.190) | (1.173) | (1.162) | (1.088) | (1.547) | (0.458) |
| Participating pref. | -0.230*** | | | -0.238*** | -0.201** | -0.0232 |
| | (0.0614) | | | (0.0653) | (0.0912) | (0.0432) |
| VC has board seat | | 0.141 | | 0.136 | 0.280 | 0.241** |
| | | (0.196) | | (0.198) | (0.219) | (0.103) |
| Pay to play | | | 0.0871 | 0.115 | 0.376*** | 0.207** |
| | | | (0.124) | (0.133) | (0.135) | (0.0773) |
| Constant | -4.608*** | -4.944*** | -4.807*** | -4.704*** | -4.527*** | 2.678*** |
| | (0.571) | (0.587) | (0.505) | (0.655) | (0.611) | (0.343) |
| Observations | 1607 | 1607 | 1607 | 1607 | 1549 | 1695 |
| Pseudo-$R^2$ | 0.0602 | 0.0557 | 0.0552 | 0.0617 | 0.195 | |
| Year FE | Y | Y | Y | Y | Y | Y |
| Year founded FE | Y | Y | Y | Y | Y | |
| State FE | Y | Y | Y | Y | Y | Y |
| Industry FE | Y | Y | Y | Y | Y | Y |

Table IV: Empirical and theoretical moments.

This table describes empirical moments and their theoretical counterparts computed at estimated model parameters. Success outcomes are captured by the ‘IPO or Acq. $> 2X$’ variable.

| **Moment** | Empirical | Theoretical |
|---|---|---|
| Avg. time since last VC financing | 0.6892 | 0.5152 |
| Var. time since last VC financing | 1.2756 | 0.4334 |
| Avg. share of VC equity | 0.3961 | 0.3892 |
| Var. share of VC equity | 0.0309 | 0.0078 |
| Skew. share of VC equity | 0.0018 | -0.0015 |
| Cov. time since last VC financing and share of VC equity | 0.0029 | 0.0048 |
| Avg. participation | 0.5121 | 0.4653 |
| Cov. time since last VC financing and participation | 0.0546 | 0.0183 |
| Cov. share of VC equity and participation | 0.0154 | 0.0314 |
| Avg. pay-to-play | 0.1227 | 0.0689 |
| Cov. time since last VC financing and pay-to-play | -0.0029 | -0.0125 |
| Cov. share of VC equity and pay-to-play | 0.0115 | -0.0076 |
| Cov. participation and pay-to-play | 0.0180 | -0.0321 |
| Avg. VC board seat | 0.8932 | 0.9213 |
| Cov. time since last VC financing and VC board seat | -0.0178 | 0.0103 |
| Cov. share of VC equity and VC board seat | 0.0062 | 0.0145 |
| Cov. participation and VC board seat | 0.0039 | 0.0366 |
| Cov. pay-to-play and VC board seat | 0.0048 | 0.0039 |
| Avg. success rate | 0.1274 | 0.1014 |
| Cov. time since last VC financing and success rate | -0.0144 | 0.0241 |
| Cov. share of VC equity and success rate | 0.0044 | 0.0021 |
| Cov. participation and success rate | -0.0122 | 0.0112 |
| Cov. pay-to-play and success rate | 0.0050 | 0.0003 |
| Cov. VC board seat and success rate | 0.0018 | 0.0039 |

Table V: Parameter estimates.

Parameter estimates of the dynamic search and matching model. Success outcomes are captured by the 'IPO or Acq. $> 2X$' variable. Significance: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

| **Parameter** | Estimate | Standard error |
|---|---|---|
| Distribution of qualities, $a_i$ | 2.4930** | 1.2281 |
| Distribution of qualities, $b_i$ | 3.5789** | 1.5380 |
| Distribution of qualities, $a_e$ | 3.9282*** | 1.1188 |
| Distribution of qualities, $b_e$ | 3.9196** | 1.5791 |
| Frequency of encounters, $\lambda_i$ | 11.6928*** | 2.9142 |
| Frequency of encounters, $\lambda_e$ | 7.6897** | 3.4068 |
| Substitutability of qualities, $\rho$ | -1.4308*** | 0.0654 |
| Probability of success, intercept, $\kappa_0$ | -5.5256** | 2.4594 |
| Probability of success, total value, $\kappa_1$ | 0.1295* | 0.0724 |
| Total value, share of VC equity, $\beta_1$ | 0.7787*** | 0.1195 |
| Total value, share of VC equity squared, $\beta_2$ | -2.4489*** | 0.1562 |
| Total value, participation, $\beta_3$ | -0.1507*** | 0.0193 |
| Total value, pay-to-play, $\beta_4$ | 0.0232 | 0.0240 |
| Total value, VC board seat, $\beta_5$ | -0.0231* | 0.0128 |
| Total value, participation $\times$ pay-to-play, $\beta_6$ | 0.0136 | 0.0304 |
| Total value, participation $\times$ VC board seat, $\beta_7$ | 0.0332* | 0.0193 |
| Total value, pay-to-play $\times$ VC board seat, $\beta_8$ | 0.0136 | 0.0191 |
| Split of value, intercept, $\gamma_1$ | -0.1895* | 0.1078 |
| Split of value, participation, $\gamma_2$ | -0.1675*** | 0.0185 |
| Split of value, pay-to-play, $\gamma_3$ | 0.0538*** | 0.0155 |
| Split of value, VC board seat, $\gamma_4$ | -0.0391** | 0.0196 |
| Split of value, participation $\times$ pay-to-play, $\gamma_5$ | 0.0110 | 0.0292 |
| Split of value, participation $\times$ VC board seat, $\gamma_6$ | 0.0257 | 0.0185 |
| Split of value, pay-to-play $\times$ VC board seat, $\gamma_7$ | 0.0101 | 0.0154 |

Table VI: Start-up values, deal frequencies, and present values of deals in the VC market at estimated parameters.

Panel A reports expected total value and its split across all deals and deals completed by quartiles of VC and entrepreneur qualities. Expected total values in subsamples, $\pi^*(Sub)$, are percentages of the expected total value across all deals, $\pi^*(All)$. Expected values of VCs and entrepreneurs in subsamples, $\pi_j^*(Sub)$, $j \in \{i, e\}$, are percentages of the expected total value in the subsample, $\pi^*(Sub)$. Panel B reports expected deal frequencies across all VCs and entrepreneurs and by quartiles of VC and entrepreneur qualities, $\Lambda^*(Sub)$. Panel C reports present values of all VCs and entrepreneurs in the market and by quartiles of VC and entrepreneur qualities, $PV^*(Sub)$, as percentages of the present value of all deals in the market, $PV^*(All)$.

**Panel A: Start-up values**

| Ratio of expected profits | $\frac{\pi^*(Sub)}{\pi^*(All)}$ | $\frac{\pi_i^*(Sub)}{\pi^*(Sub)}$ | $\frac{\pi_e^*(Sub)}{\pi^*(Sub)}$ |
|---|---|---|---|
| Investor | | | |
| All deals | 100 | 49.06 | 50.94 |
| 0-10% quantile | 14.32 | 49.05 | 50.95 |
| 10-50% quantile | 64.84 | 48.54 | 51.46 |
| 50-90% quantile | 155.26 | 48.44 | 51.56 |
| 90-100% quantile | 241.27 | 53.13 | 46.87 |
| Entrepreneur | | | |
| All deals | 100 | 49.06 | 50.94 |
| 0-10% quantile | 2.99 | 52.87 | 47.13 |
| 10-50% quantile | 21.00 | 51.14 | 48.86 |
| 50-90% quantile | 85.77 | 49.82 | 50.18 |
| 90-100% quantile | 198.06 | 47.98 | 52.02 |

**Panel B: Deal frequencies**

| Frequency of deals | $\Lambda^*(Sub)$ |
|---|---|
| Investor | |
| All deals | 2.153 |
| 0-10% quantile | 2.251 |
| 10-50% quantile | 2.654 |
| 50-90% quantile | 1.860 |
| 90-100% quantile | 1.126 |
| Entrepreneur | |
| All deals | 1.416 |
| 0-10% quantile | 0.088 |
| 10-50% quantile | 0.550 |
| 50-90% quantile | 2.153 |
| 90-100% quantile | 3.257 |

**Panel C: Present values of deals**

| Ratio of $PV$ of deals | $\frac{PV^*(Sub)}{PV^*(All)}$ |
|---|---|
| Investor | |
| All deals | 56.47 |
| 0-10% quantile | 0.57 |
| 10-50% quantile | 13.08 |
| 50-90% quantile | 30.91 |
| 90-100% quantile | 11.91 |
| Entrepreneur | |
| All deals | 43.53 |
| 0-10% quantile | 0.09 |
| 10-50% quantile | 4.44 |
| 50-90% quantile | 23.81 |
| 90-100% quantile | 15.19 |

Table VII: Start-up values, deal frequencies, and present values of deals in the VC market in the presence of contract features regulation.

This table examines the effect of three counterfactuals, in which investors are restricted from including contractual features implemented via (a) participation preference, (b) pay-to-play, and (c) the VC board seat. Panel A reports the change in the expected firm value and its split across all deals. *Rebalanced terms only* rows report the partial effect of rebalancing the remaining contract terms such that the set of matches does not change, and *Equilibrium* rows report the aggregate effect of rebalancing and rematching in the new equilibrium. The change in the expected firm value across all deals, $\Delta\pi^{cf}(All) = \pi^{cf}(All) - \pi^*(All)$, and the change in expected values of VCs and entrepreneurs , $\Delta\pi_j^{cf}(All) = \pi_j^{cf}(All) - \pi_j^*(All)$, $j \in \{i, e\}$, are percentages of the estimated expected firm value across all deals, $\pi^*(All)$. Panel B reports the change in expected deal frequencies in the market, $\Delta\Lambda^{cf}(All) = \Lambda^{cf}(All) - \Lambda^*(All)$, as percentages of the estimated deal frequency in the market, $\Lambda^*(All)$. Panel C reports the change in present values of all deals in the market, $\Delta PV^{cf}(All) = PV^{cf}(All) - PV^*(All)$, and the change in present values of all VCs and entrepreneurs, $\Delta PV_j^{cf}(All) = PV_j^{cf}(All) - PV_j^*(All)$, $j \in \{i, e\}$, as percentages of the estimated present value of deals in the market, $PV^*(All)$.

**Panel A: Start-up values**

| Ratio of expected profits | $\frac{\Delta\pi^{cf}(All)}{\pi^*(All)}$ | $\frac{\Delta\pi_i^{cf}(All)}{\pi^*(All)}$ | $\frac{\Delta\pi_e^{cf}(All)}{\pi^*(All)}$ |
|---|---|---|---|
| No participation preference | | | |
| Rebalanced terms only | -0.06 | -0.06 | 0 |
| Equilibrium | 1.65 | 0.46 | 1.20 |
| No pay-to-play | | | |
| Rebalanced terms only | 0 | 0 | 0 |
| Equilibrium | 0 | 0 | 0 |
| No VC board seats | | | |
| Rebalanced terms only | -0.20 | -0.20 | 0 |
| Equilibrium | 0.65 | -0.30 | 0.95 |

**Panel B: Deal frequencies**

| Ratio of deal frequencies | $\frac{\Delta\Lambda^{cf}(All)}{\Lambda^*(All)}$ |
|---|---|
| No participation preference | -2.40 |
| No pay-to-play | 0 |
| No VC board seat | 0 |

**Panel C: Present values of deals**

| Ratio of present values | $\frac{\Delta PV^{cf}(All)}{PV^*(All)}$ | $\frac{\Delta PV_i^{cf}(All)}{PV^*(All)}$ | $\frac{\Delta PV_e^{cf}(All)}{PV^*(All)}$ |
|---|---|---|---|
| No participation preference | 0.55 | -0.18 | 0.73 |
| No pay-to-play | 0 | 0 | 0 |
| No VC board seat | 0.48 | -0.33 | 0.81 |

Table VIII: Start-up values, deal frequencies, and present values of deals in the VC market when search frictions are low.

The table examines effects of three counterfactuals, in which VCs and entrepreneurs encounter each other with 2X, 5X, and 10X higher frequency compared to the estimated frequency. It reports the change in present values of all deals in the market, $\Delta PV^{cf}(All) = PV^{cf}(All) - PV^{*}(All)$, and the change in present values of all VCs and entrepreneurs, $\Delta PV_j^{cf}(All) = PV_j^{cf}(All) - PV_j^{*}(All)$, $j \in \{i, e\}$, as percentages of the estimated present value of deals in the market, $PV^{*}(All)$. Table A2 in the appendix provides the detailed analysis of quartiles of VC and entrepreneur qualities.

| Ratio of present values | $\frac{\Delta PV^{cf}(All)}{PV^{*}(All)}$ | $\frac{\Delta PV_i^{cf}(All)}{PV^{*}(All)}$ | $\frac{\Delta PV_e^{cf}(All)}{PV^{*}(All)}$ |
|---|---|---|---|
| 2X more frequent encounters | -2.00 | 2.16 | -4.16 |
| 5X more frequent encounters | -5.81 | 4.57 | -10.39 |
| 10X more frequent encounters | -5.88 | 5.87 | -11.75 |

# Appendix

## A Proof of Proposition 1

The agents' expected present values are

$$V_i(i) = \frac{1}{1+rdt}\left(\lambda_i dt\left(\int_{e\in\mu_i(i)} \max\{\pi_i(i,e,c^*), V_i(i)\} dF(e) + \int_{e\notin\mu_i(i)} V_i(i) dF(e)\right) + (1-\lambda_i dt)V_i(i)\right), \quad (15)$$

$$V_e(e) = \frac{1}{1+rdt}\left(\lambda_e dt\left(\int_{i\in\mu_e(e)} \max\{\pi_e(i,e,c^*), V_e(e)\} dF(i) + \int_{i\notin\mu_e(e)} V_e(e) dF(i)\right) + (1-\lambda_e dt)V_e(e)\right) \quad (16)$$

Consider the expression for $V_i(i)$ ($V_e(e)$ is symmetric). Multiply both sides by $1+rdt$, cancel out the two terms that contain $V_i(i)$ but not $dt$, and divide by $dt$ to obtain

$$rV_i(i) = \lambda_i \int_{e\in\mu_i(i)} \max\{\pi_i(i,e,c^*), V_i(i)\} dF(e) + \lambda_i \int_{e\notin\mu_i(i)} V_i(i) dF(e) - \lambda_i V_i(i).$$

Move $\lambda_i V_i(i)$ to the right-hand side and divide everything by $r+\lambda_i$. Equation (8) follows.

## B Example contract terms: Reata Pharmaceuticals (NAS: RETA)

Here we present sections of Reata Pharmaceuticals 2003 Series A certificate of incorporation.[32]

### B.1 Equity sold and share price

The Series A investors purchased 1,751,000 shares at $1.00/share at an approximate $8.25m pre-money, $10m post-money valuation (17.5% of equity):

> The total number of shares of capital stock that the Corporation shall have authority to issue is 90,000,000, consisting of 55,000,000 shares of common stock, par value $0.001 per share (the "Common Stock"), and 35,000,000 shares of preferred stock, par value $0.001 per share (the "Preferred Stock"). [...] 1,751,000 shares of Preferred Stock are designated as the Corporation's Series A Convertible Preferred Stock (the "Series A Preferred Stock"). [...] for each share of Series A Preferred Stock then held by them equal to $1.00 (as adjusted for any stock splits, stock dividends, recapitalizations, combinations, or similar transactions with respect to such shares after the filing date of this Certificate, the "Original Issue Price").

The equity stake sold is calculated by data providers Pitchbook and VC Experts using a proprietary model that estimates the total number of issued shares out of the total shares authorized. Pitchbook estimates that a total of 10 million shares were issued at the time of the Series A financing.[33]

[32] A pdf version is available here: `https://its.caltech.edu~/mewens/vc_contracts/reata_pharmaceuticals.pdf`.

[33] See `https://my.pitchbook.com/profile/44160-31/company/profile#deal-history/19114-57T`.

### B.2 Cumulative dividends

The following details the cumulative dividends available to the Series A investors:

> The holders of the outstanding shares of Series A Preferred Stock shall be entitled to receive dividends from time to time out of any assets legally available for payment of dividends equal to $0.08 per annum per share [...] Dividends on each share of Series A Preferred Stock shall be cumulative and shall accrue on each share from day to day until paid, whether or not earned or declared, and whether or not there are profits, surplus, or other funds legally available for the payment of dividends.

### B.3 Liquidation preference and participation

This section details the liquidation preference for the Series A shareholders:

> The Series A Preferred Stock ranks senior with respect to distributions on liquidation to any Equity Securities that do not by their terms rank senior to or on a parity with Series A Preferred Stock, including the Common Stock. In the event of any liquidation, dissolution, or winding up of the Corporation, either voluntary or involuntary, the holders of the Series A Preferred Stock shall be entitled to receive, after payment or distribution and setting apart for payment or distribution of any of the assets or surplus funds of the Corporation required to be made to the holders of Liquidation Senior Stock (the "Liquidation Senior Stock Preference"), but prior and in preference to any payment or distribution and setting apart for payment or distribution of any of the assets or surplus funds of the Corporation to the holders of the Common Stock and to the holders of any other Equity Securities ranking junior to the Series A Preferred Stock with respect to distributions on liquidation, an amount for each share of Series A Preferred Stock then held by them equal to $1.00. [...] plus all accrued or declared but unpaid dividends on the Series A Preferred Stock up to and including the date of payment of such Liquidation Preference (the "Liquidation Preference").

This text details the participation rights of the Series A investors:

> If, after full payment of the Liquidation Senior Stock Preference, if any, the assets and funds of the Corporation legally available for distribution to the Corporation's stockholders exceed the aggregate Liquidation Preference payable pursuant to Section 2.2(a) [i.e, see quote above] of this Article Four, then, after the payments required by Section 2.2(a) of this Article Four shall have been made or irrevocably set apart for payment, the remaining assets and funds of the Corporation available for distribution to the Corporation's stockholders shall be distributed pro rata among (i) the holders of the Common Stock, (ii) the holders of the Series A Preferred Stock (with each such holder of Series A Preferred Stock being treated for this purpose as holding the greatest whole number of shares of Common Stock then issuable upon conversion of all shares of Series A Preferred Stock held by such holder pursuant to Section 2.5 of this Article Four), and (iii) among the holders of any other Equity Securities having the right to participate in such distributions on liquidation, in accordance with the respective terms thereof.

### B.4 Board rights

Along with data collected by data providers such as VentureSource and Pitchbook, the certificate of incorporation shows that the Series A investors also have at least one board seat:

> [I]ncluding at least one member of the Board appointed by the holders of the Series A Preferred Stock.

## C Contraction mapping details

The discrete-time representation derived in Proposition 1 allows to to numerically solve the contraction mapping (8) and (9) as the system of interdependent Bellman equations. Specifically,

1. We assume that $F_i(i)$ and $F_e(e)$ are flexible Beta distributions. We discretize qualities $i \sim F_i(i)$ and $e \sim F_e(e)$ by using a quadrature with 25 points for each distribution, resulting in 625 possible combinations of partner qualities. This gives a very precise solution.

2. For any $i$ and $e$, we set the initial guess of continuation values equal to $V^0 = (V_i^0(i), V_e^0(e)) = (0, \bar{V})$, where $\bar{V}$ is sufficiently large. For example, if the only contract term is the fraction of equity that the investor retains, then $\bar{V} = v_e(\bar{i}, \bar{e}, 0)$: the entrepreneur is guessed to retain the entire firm.[34] For any $i$ and $e$, we set the initial guess of qualities of those agents from the opposite population, who are willing to match, equal to $(\mu_i^0, \mu_e^0) = (\mu_i^0(i), \mu_e^0(e)) = (\mathbf{1}_{i=\bar{i}}[\underline{e}, \bar{e}], [\underline{i}, \bar{i}])$. This choice implies that few agents are initially guessed to match, so the initial update to $V^0$, explained below, is smooth.

3. For every $n \geq 1$, we obtain $V^n = (V_i^n(i), V_e^n(e))$ and $(\mu_i^n, \mu_e^n) = (\mu_i^n(i), \mu_e^n(e))$ by inputting $V^{n-1}$ and $(\mu_i^{n-1}, \mu_e^{n-1})$ into the right-hand side of the system of equations (8)–(9) and solving for the left-hand side. Because the system is a contraction mapping, $V = \lim_{n\to\infty} V^n$ is the equilibrium.[35] We stop the process when $\|V^n - V^{n-1}\| < \varepsilon$, where $\varepsilon > 0$ is sufficiently small.

## D Derivation of theoretical moments

Let $w_e$ be the discretized probability that an investor meets an entrepreneur of quality $e$; $w_i$ be the discretized probability that an entrepreneur meets an investor of quality $i$; and the match indicator $m(i, e) = 1$ if $i$ and $e$ form a start-up, and zero otherwise.

[34] The static matching literature shows that this initial guess is consistent with an entrepreneur making an offer to match with a sufficiently good investor, and leads to computation of the so-called "entrepreneur-friendly" equilibrium. This terminology is somewhat confusing in the dynamic setting with contracts, as, once encountered and offered to match, it is an investor who offers the contract to an entrepreneur. The situation where the entrepreneur approaches the investor but is offered a take-it-or-leave-it contract in return is consistent with practice in the venture capital market. Our robustness checks explore the situation when the entrepreneur has extra bargaining power in addition to its threat to walk away from the deal and match with a different investor in the future.

[35] We use the value iteration method to make sure the solution does not jump between potential multiple equilibria.

### D.1 Contract-related moments

The expected value of contract term $c_k^*(i,e)$, $k \in \{1..D\}$ across all deals is

$$E(c_k^*) = \frac{\sum_i \sum_e w_i w_e m(i,e) c_k^*(i,e)}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{17}$$

The variance of $c_k^*(i,e)$ across all deals is

$$V(c_k^*) = \frac{\sum_i \sum_e w_i w_e m(i,e)(c_k^*(i,e) - E(c_k^*))^2}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{18}$$

For terms that only take values of zero or one, the variance does not contain additional, compared to the expected value, information, so we do not use it in the estimation. Finally, the covariance between any two contract terms $c_k^*(i,e)$ and $c_l^*(i,e)$, $k,l \in \{1..D\}$ across all deals is

$$Cov(c_k^*, c_l^*) = \frac{\sum_i \sum_e w_i w_e m(i,e)(c_k^*(i,e) - E(c_k^*)) \cdot (c_l^*(i,e) - E(c_l^*))}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{19}$$

### D.2 Moments related to expected time between deals

Recall that after a successful deal, the distribution of the number of new encounters for investor $i$ is a Poisson random variable with intensity $\lambda_i$. Each encounter, in equilibrium, results in a deal with probability $p_i = \sum_e w_e m(i,e)$. The distribution of the number of deals, conditional on $k$ meetings, is therefore an independent Binomial distribution with number of trials $k$ and success probability $p_i$. This implies that the distribution of the number of deals is a Poisson distribution with intensity $\lambda_i p_i$. Therefore, the time between deals, $\tau$, for investor $i$ has mean and variance equal to

$$E(\tau|i) = \frac{1}{\lambda_i p_i}; \quad V(\tau|i) = \frac{1}{(\lambda_i p_i)^2}. \tag{20}$$

Across all deals done by investors with different qualities, the expected time between deals is, from the law of iterated expectations,

$$E(\tau) = E[E(\tau|i)] = \sum_i w_i^* E(\tau|i),$$

where $w_i^* = w_i \frac{\sum_e w_e m(i,e)}{\sum_i \sum_e w_i w_e m(i,e)}$ is the equilibrium share of deals done by investor $i$ among all deals. This is different from $w_i$, the probability distribution of investors, because some investors match more frequently than others. Inserting $w_i^*$ into the above equation and using (20),

$$E(\tau) = \frac{\sum_i \sum_e w_i w_e m(i,e) \frac{1}{\lambda_i p_i}}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{21}$$

Because $\tau$ is random for any given deal, its variance is, from the law of total variance,

$$V(\tau) = E[V(\tau|i)] + V[E(\tau|i)]. \tag{22}$$

Using (20), the first term of (22) is

$$E[V(\tau|i)] = \frac{\sum_i \sum_e w_i w_e m(i,e) \frac{1}{(\lambda_i p_i)^2}}{\sum_i \sum_e w_i w_e m(i,e)};$$

additionally using (21), the second term is

$$V[E(\tau|i)] = \sum_i w_i^* (E(\tau|i) - E(\tau))^2 = \frac{\sum_i \sum_e w_i w_e m(i,e) \left(\frac{1}{\lambda_i p_i} - E(\tau)\right)^2}{\sum_i \sum_e w_i w_e m(i,e)},$$

The covariances between $\tau$ and contract term $c_k^*(i,e)$, $k \in \{1..D\}$ across all deals can similarly be derived from the law of total covariance,

$$Cov(\tau, c_k^*) = E[Cov(\tau, c_k^*|i)] + Cov[E(\tau|i), E(c_k^*|i)] \tag{23}$$

The first term of (23) is zero, because the time between deals does not vary with contract terms for a given investor. Using (17), (20), (21), and $E(c_k^*|i) = \frac{\sum_e w_e m(i,e) c_k^*(i,e)}{\sum_i \sum_e w_i w_e m(i,e)}$, the second term is

$$\begin{aligned} Cov[E(\tau|i), E(c_k^*|i)] &= \sum_i w_i^* (E(\tau|i) - E(\tau)) \cdot (E(c_k^*|i) - E(c_k^*)) \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e) \left(\frac{1}{\lambda_i p_i} - E(\tau)\right) \cdot (c_k^*(i,e) - E(c_k^*))}{\sum_i \sum_e w_i w_e m(i,e)}. \end{aligned}$$

### D.3 Success outcome-related moments

Recall that the probability of success for a given deal is

$$Pr(Success = 1|i,e) = \Phi(\kappa_0 + \kappa_1 \cdot \pi(i,e,c^*(i,e))), \tag{24}$$

with $\Phi$ the standard normal c.d.f. The expected success rate across all deals is then

$$\begin{aligned} E(Success) &= E\left[E(Success = 1|i,e)\right] \\ &= E\left[Pr(Success = 1|i,e)\right] \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e) \Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e)))}{\sum_i \sum_e w_i w_e m(i,e)}. \end{aligned} \tag{25}$$

Similarly to (22), because *Success* is random for any given deal, its variance is, from the law of total variance,

$$\begin{aligned} V(Success) &= E(V(Success|i,e)) + V(E(Success|i,e)) \\ &= E(Pr(Success = 1|i,e) \cdot (1 - Pr(Success = 1|i,e))) + V(Pr(Success = 1|i,e)) \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e) \Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))) \cdot (1 - \Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))))}{\sum_i \sum_e w_i w_e m(i,e)} \\ &\quad + \frac{\sum_i \sum_e w_i w_e m(i,e)(\Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))) - E(Success))^2}{\sum_i \sum_e w_i w_e m(i,e)}, \end{aligned} \tag{26}$$

where we use (24) and (25) to arrive at the final expression.

The covariances between $Success$ and contract term $c_k^*(i,e)$, $k \in \{1..D\}$ across all deals are

$$\begin{aligned} Cov(Success, c_k^*) &= E(Cov(Success, c_k^*|i,e)) + Cov(E(Success|i,e), E(c_k^*|i,e)) \\ &= Cov(Pr(Success|i,e), c_k^*(i,e)) \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e)(\Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))) - E(Success)) \cdot (c_k^*(i,e) - E(c_k^*))}{\sum_i \sum_e w_i w_e m(i,e)}, \end{aligned} \tag{27}$$

where $E(Cov(Success, c_k^*|i,e))$ is zero because the contract is deterministic for a given pair of investor and entrepreneur, and therefore does not vary with the start-up's success outcome. To arrive at the final expression, we use (17), (24), and (25).

Finally, the covariance between $Success$ and $\tau$ across all deals is

$$\begin{aligned} Cov(\tau, Success) &= E[Cov(\tau, Success|i)] + Cov[E(\tau|i), E(Success|i)] \\ &= Cov[E(\tau|i), E(Success|i)] \\ &= \sum_i w_i[E(\tau|i) - E(\tau)] \cdot [E(Success|i) - E(Success)] \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e) \left(\frac{1}{\lambda_i p_i} - E(\tau)\right) \cdot (\Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))) - E(Success))}{\sum_i \sum_e w_i w_e m(i,e)}, \end{aligned} \tag{28}$$

where $E[Cov(\tau, Success|i)]$ is zero because the time between deals does not vary with the start-up's success outcome for a given investor. To arrive at the final expression, we use (20), (21), (24), (25), and $E(IPO|i) = \frac{\sum_e w_e m(i,e) Pr(IPO|i,e)}{\sum_i \sum_e w_i w_e m(i,e)} = \frac{\sum_e w_e m(i,e) \Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e)))}{\sum_i \sum_e w_i w_e m(i,e)}$.

## E Positively assortative matching in matching models with contracts

Figure 1 shows that better VCs tend to match with better entrepreneurs, but this pattern is imperfect. The following proposition shows that if the contracts were, instead, exogenous, and the matching function $g(i,e)$ exhibited a sufficient degree of complementarity, we would obtain positively assortative matching (e.g., good VCs would always match with good entrepreneurs):

**Proposition 2.** *Suppose that $\rho \le 0$ in specification (10) for $g(i,e)$, and that $c^*(i,e) \equiv const$ is exogenous. Then, the model solution admits positively assortative matching.*

Proof: The result follows from Shimer and Smith (2000) and Smith (2011). Specifically, when $\rho = 0$ and $c^*(i,e) \equiv const$, $\pi(i,e,c^*)$ depends on types $i$ and $e$ multiplicatively and is therefore log-modular. As a result, the model solution admits block segregation, in which VCs within a certain band of qualities only match with entrepeneurs within a certain band of qualities and never with anyone else, and vice versa. Formally, for $k \ge 1$, any VC quality $[\hat{i}_k, \hat{i}_{k-1}]$ matches with any entrepreneur quality $[\hat{e}_k, \hat{e}_{k-1}]$, where $(\hat{i}_0, \hat{e}_0) = (\bar{i}, \bar{e})$ and $(\hat{i}_k, \hat{e}_k)$, $k \ge 1$ are endogenous functions of model parameters. Block segregation immediately implies positively assortative matching. Further, when $\rho < 0$ and $c^*(i,e) \equiv const$, $\pi(i,e,c^*)$ is log-supermodular, which implies strict positively assortative matching.

When contracts are endogenous, there is no guarantee that the model solution admits positively assortative matching. In particular, Figure 1 shows that this matching pattern does not occur under our parameter estimates. Intuitively, because contracts are chosen endogenously, it can pay, for a lower-quality VC who otherwise would have been excluded by the best entrepreneurs, to offer a larger fraction of the start-up to these entrepreneurs to make a deal. The lower the VC quality, the higher is the fraction it has to offer to a given entrepreneur, and the higher is the cut-off on the entrepreneur quality, at which this VC can benefit.[36] This result calls into question the validity of simply assuming positively assortative matching in settings with contracts (e.g., Cong, 2018).

# F Robustness and extensions

## F.1 Overconfidence

There is ample evidence that entrepreneurial individuals are overconfident, i.e., assign a higher precision to their information than the data would suggest.[37] Our model is easily extendable to allow for overconfidence on the part of agents. Modify (5) and (6) as

$$\begin{aligned} \pi_i^j(i,e,c^*) &= \alpha(c^*)\cdot\pi^j(i,e,c^*), && (29)\\ \pi_e^j(i,e,c^*) &= (1-\alpha(c^*))\cdot\pi^j(i,e,c^*), && (30)\end{aligned}$$

where superscript $j \in \{i,e\}$ indicates that VCs and entrepreneurs compute the total value and its split using potentially different beliefs. Let counterparty $j \in \{i,e\}$ believe that with probability $p_j$, signal $e$ about entrepreneur quality is correct, and with probability $1-p_j$, the signal is completely uninformative, so that entrepreneur quality is a random draw from $F_e(e)$. Then, $\pi^j(i,e,c^*) = i\cdot(p_j e + (1-p_j)\bar{e})\cdot h(c^*)$. For example, the case of entrepreneurs entirely relying on the signal about their quality but VCs doubting it is $p_e = 1$ and $p_i < 1$. In the presence of the difference in beliefs, the incentive rationality condition of the entrepreneur, (7), becomes

$$c^*(i,e) = \underset{c\in C:\pi_e^e(i,e,c)\geq V_e(e)}{\arg\max}\ \pi_i^i(i,e,c). \qquad (31)$$

Note that even though the VC solves its optimization problem under its own beliefs, it has to provide the entrepreneur with at least its expected present value from continued search under the *entrepreneur's* beliefs. We compare parameter estimates of the main model with those of the modified model for $(p_i,p_e) = (0.75,1)$. Panel B of Table A6 shows that even a rather substantial entrepreneurial overconfidence does not appear to affect the estimates.

[36] Formally, the VC's payoff may not be log-supermodular in the deal, in which an entrepreneur of the highest quality matches with a VC of the lowest quality allowed for such an entrepreneur in equilibrium: $\frac{\partial\pi_i\left(i,e,c^*(i,e)\right)}{\partial i\partial e} < 0$ (see Theorem 1 in Smith (2011)).

[37] Theoretical and empirical research on entrepreneural overconfidence includes Cooper, Woo, and Dunkelberg (1988), Busenitz and Barney (1997), Camerer and Lovallo (1999), Bernardo and Welch (2001).

### F.2 Match-specific shocks

Two key results of the main model is that the set of counterparties a VC or entrepreneur matches with is fixed in equilibrium (however, within this set, the agents can match randomly), and that a given combination of agents always signs the same contract. One limitation of our model is that in reality, deal-specific information revealed during due diligence and contract negotiation may prevent a match between good-quality counterparties or allow a match between counterparties of vastly different qualities, or result in very different contracts between identical pairs of VCs and entrepreneurs by quality. Another limitation is that for many parameters, the model imposes a theoretical bound on the VC fraction of equity and firm value, which is estimated at 45.7% and 53.1%. However in practice, there are deals in which VCs sign deals with more VC-friendly terms.

To address both concerns, we extend the model to include match-specific shocks. Specifically, we change (4) as

$$\pi(i, e, c, z) = g(i, e) \cdot h(c, z), \tag{32}$$

where $z$ is a match-specific shock drawn from $N(0, \sigma^2)$. An alternative specification, in which $z$ affects $g$ instead, gives similar results but does not address the second limitation of the main model, because the bound on VC-friendly contracts is entirely determined by $h$. $h(c, z)$ is parameterized as

$$h(c^*, z) = \exp\left\{\beta_1 c_1^* + (\beta_2 + z)c_1^{*2} + \beta'_{3:D+1} c_1^*(1 - c_1^*)c_{2:D}^*\right\}. \tag{33}$$

The idea behind this particular parameterization is that deals between identical pairs of VCs and entrepreneurs by quality can still differ in terms of entrepeneurial risks and cost of effort, and agency conflicts between the parties, which tend to be more important as the VC owns a larger fraction of the firm. Alternative parameterizations, in which $z$ impacts $\beta_1$ or all coefficients at once, give similar results.

Due to computational complexity of adding an additional state variable, we discretize quality distributions on a 40 point grid and the distribution of match-specific shocks on a 5 point grid. Figure A.XXX shows contracts for all feasible combinations of VC and entrepreneur qualities, and the lowest and highest realization of the match-specific shock produced by the model at estimated parameter values. The extended model imposes a much higher theoretical bound on the VC fraction of equity (for low realizations of $z$), which encapsulates all observable deals. Panel C of Table A6 shows that the addition of a match-specific shock does not substantially affect the estimates.

### F.3 Investment amount

In the main model, we do not treat capital raised by an entrepreneur as an endogenous contract term. This assumption is consistent with the view that the entrepreneur's idea requires a fixed amount of capital and constitutes a fraction of the entrepreneur's quality. An alternative polar case would be to treat capital raised as an entirely endogenous term. This assumption is consistent with the view that it is the entrepreneur's intrinsic quality, but not the start-up's financing requirements, that determines the amount of capital a VC will give it. The reality is somewhere in between the two polar cases. Entrepreneurs may be unable to realize their idea at all if the amount of capital is below a certain threshold, while incremental improvements from the amount of capital above their initial estimate may be modest. Additionally, legal conventions in VC agreements produce a natural upper bound on capital invested in a single start-up. In particular, VCs typically cannot have an investment in any start-up exceed 10-15% of the total fund size.

In this section, we take an alternative polar view that capital raised is entirely endogenous. Specifically, we modify (11) as

$$h(c^*) = \exp\left\{\beta_0 \log c_0^* + \beta_1 c_1^* + \beta_2 c_1^{*2} + \beta_{3:D+1}'(1-c_1^*)c_{2:D}^*\right\}, \tag{34}$$

and modify (5) as

$$\pi_i(i,e,c^*) = \phi(c_0^*) \cdot \alpha(c^*) \cdot \pi(i,e,c^*), \tag{35}$$

keeping (6) unchanged. Equation (34) implies that the matching function in the presence of endogenous investment exhibits returns to scale with factor $\beta_0$. Equation (35) implies that the VC experiences costs of investment $1-\phi(c_0^*)$ per unit of profit. These include direct costs, such as loss of $c_0^*$ at the time of financing, and indirect costs, such as time and effort spent monitoring and making decisions on the board of directors. We parameterize $\phi(c_0^*) = \exp\{\gamma_0 c_0^*\}$.[38]

The model with endogenous investment (an additional continuous contract term) is very computationally complex, therefore we do not attempt to estimate it. Instead, we examine its comparative statics with respect to $\beta_0$ and $\gamma_0$. For all reasonable parameter values, the model produces several unsatisfactory results. First, for a given entrepreneur, investments by the worst VCs it matches with are substantially higher than by the best VCs, as the worst VCs try to retain better entrepreneurs despite (as a practical concern) facing tighter upper bounds on capital invested in a single start-up. Second, this pattern of investments results in a lower variance of the VC equity share, moving it farther away from that in the data. Finally, the dispersion of VC investments scaled by the industry-time average investment in the data is 144%, but the model underestimates it by a factor of 10 even for $\beta_0$ close to 1 (high returns to scale should result in a high dispersion). A fixed entrepreneur quality-related component in the VC investment would move the model output closer to the data, but this correction essentially amounts to assuming that investments are largely exogenously determined by agents' qualities. In any case, even if investment is indeed endogenous, it does not appear to affect moments of the model unrelated to investment for all reasonable parameter values.[39] In turn, it is unlikely that the impact of other contract terms on deal values and their split would be substantially affected.

## G Calibration of the value of the convertible preferred

To rationalize the 11.8% estimated valuation gap between common equity and (nonparticipating) convertible preferred in the value-maximizing contract of the search model, consider the following example. A start-up raises \$1 million at a \$4 million valuation using a preferred equity security that is convertible into 16.2% of common equity (the estimated value-maximizing equity share). As is common for first rounds, the liquidation preference is 1X. The annual risk-free rate is 2% and the expected time until exit is 7 years (these are the average numbers over our sample period). For simplicity, assume no future financing rounds are expected to be necessary.

Metrick and Yasuda (2010) derive the contingent claims valuation of convertible preferred equity. Under the above assumptions, the Black-Scholes value of the convertible preferred is \$1.01m, or 25.2% of firm value, which is close to the estimated 28% of firm value that the VC

[38] It is easy to justify the positive relationship between total costs of investment and the VC share of the firm via a simple model. See, e.g., Grossman and Hart (1986).

[39] These results are available from the authors upon request.

receives in our model. Relative to 16.2% of common equity, the convertible preferred feature is thus worth 9% of firm value.

The contingent claims example ignores other contractual features of the convertible preferred equity security, such as voting rights and protective provisions, which are nearly always present. These features increase the security's value and widen the valuation gap with common equity.

Note that the true \$4m valuation is different from the post-money valuation computed as \$1m/.162 = \$6.2 million. The post-money valuation overstates the true value because its calculation assumes common equity (Gornall and Strebulaev, 2017).

Finally, note that the estimated valuation gap between convertible preferred and common equity is substantially smaller for the average observed contract and the unconstrained VC contract.

Table A1: Summary statistics: follow-on sample.

Descriptive statistics of start-ups and their first round equity financings for the samples described in section 3. The "Follow-on sample" includes financing rounds between 2002 and 2015 where the outcome variable is a dummy variable equal to one if the startup raised a new round of financing or had a successful exit within two years of their first financing. A financing is in this sample if the equity stake and contract terms are known. "All deals" are all the financings in 2002–2015 regardless of missing data. The variables are as defined in Table I. Only means are reported for indicator variables.

Panel A: Firm and financing characteristics

| | Follow-on sample | | | | All deals 2002–2015 | | | |
|---|---|---|---|---|---|---|---|---|
| | Obs | Mean | Median | Std dev | Obs | Mean | Median | Std dev |
| Firm age at financing (yrs) | 2,581 | 1.62 | 1.15 | 1.65 | 10,613 | 1.69 | 1.17 | 1.70 |
| Information technology | 2,581 | 0.46 | 0.00 | 0.50 | 10,613 | 0.48 | 0.00 | 0.50 |
| Healthcare | 2,581 | 0.23 | 0.00 | 0.42 | 10,613 | 0.18 | 0.00 | 0.39 |
| Years since last round (VC) | 2,343 | 0.71 | 0.25 | 1.27 | 8,938 | 0.79 | 0.30 | 1.34 |
| Syndicate size | 2,581 | 1.82 | 2.00 | 1.03 | 10,613 | 1.65 | 1.00 | 1.02 |
| Capital raised in round (2012, mil.) | 2,581 | 7.21 | 4.59 | 9.27 | 9,754 | 5.50 | 2.89 | 8.16 |
| Post-money valuation (2012, mil.) | 2,581 | 22.07 | 12.93 | 41.47 | 6,104 | 19.04 | 11.40 | 34.16 |
| Financing year | 2,581 | 2008.49 | 2008.00 | 3.59 | 10,613 | 2009.60 | 2010.00 | 3.92 |
| Seed round | 2,581 | 0.15 | 0.00 | 0.36 | 10,613 | 0.23 | 0.00 | 0.42 |

Panel B: Contracts

| | Follow-on sample | | All deals 2002–2015 | |
|---|---|---|---|---|
| | Obs | Mean | Obs | Mean |
| % equity sold to investors | 2,581 | 0.37 | 6,104 | 0.35 |
| Participating pref. | 2,581 | 0.40 | 4,733 | 0.40 |
| Cumulative dividends | 2,577 | 0.17 | 4,559 | 0.19 |
| Pay to play | 2,581 | 0.10 | 3,071 | 0.10 |
| Redemption rights | 2,529 | 0.31 | 3,460 | 0.33 |
| VC has board seat | 2,581 | 0.87 | 10,613 | 0.62 |
| Liquidation mult. > 1 | 2,558 | 0.03 | 4,682 | 0.03 |
| Full ratchet | 1,642 | 0.01 | 3,379 | 0.01 |
| Common stock sold? | 2,578 | 0.08 | 4,895 | 0.05 |

Table A2: Empirical and theoretical moments of model modifications: alternative success outcome and contract definitions.

This table describes empirical moments and their theoretical counterparts of model modifications described in Section 6. Panel A describes moments of the model where success outcomes are captured by IPO. Panel B describes moments of the model where success outcomes are captured by follow-on financing. Panel C describes moments of the model where missing contract terms are imputed as zeros, provided the VC equity fraction and at least one additional term is non-missing in the data. Significance: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

| | **A. IPO** | | **B. Follow-on financing** | | **C. IPO+Acq.$> 2X$, imputed** | |
|---|---|---|---|---|---|---|
| **Moment** | Empirical | Theoretical | Empirical | Theoretical | Empirical | Theoretical |
| Avg. time since last VC financing | 0.6892 | 0.5667 | 0.7071 | 0.5554 | 0.7228 | 0.5266 |
| Var. time since last VC financing | 1.2756 | 0.4610 | 1.6014 | 0.7148 | 1.3962 | 0.4009 |
| Avg. share of VC equity | 0.3961 | 0.3875 | 0.3670 | 0.3683 | 0.3943 | 0.3927 |
| Var. share of VC equity | 0.0309 | 0.0069 | 0.0304 | 0.0063 | 0.0295 | 0.0067 |
| Skew. share of VC equity | 0.0018 | -0.0011 | 0.0031 | -0.0010 | 0.0019 | -0.0011 |
| Cov. time since last VC financing and share of VC equity | 0.0029 | 0.0038 | 0.0035 | 0.0037 | 0.0000 | 0.0039 |
| Avg. participation | 0.5121 | 0.4964 | 0.4014 | 0.4249 | 0.5150 | 0.4787 |
| Cov. time since last VC financing and participation | 0.0546 | 0.0139 | 0.0489 | 0.0161 | 0.0562 | 0.0136 |
| Cov. share of VC equity and participation | 0.0154 | 0.0328 | 0.0226 | 0.0280 | 0.0147 | 0.0304 |
| Avg. pay-to-play | 0.1227 | 0.0549 | 0.1011 | 0.0476 | 0.0853 | 0.0241 |
| Cov. time since last VC financing and pay-to-play | -0.0029 | -0.0108 | 0.0050 | -0.0067 | -0.0050 | -0.0048 |
| Cov. share of VC equity and pay-to-play | 0.0115 | -0.0066 | 0.0147 | -0.0059 | 0.0081 | -0.0033 |
| Cov. participation and pay-to-play | 0.0180 | -0.0273 | 0.0253 | -0.0202 | 0.0123 | -0.0116 |
| Avg. VC board seat | 0.8932 | 0.9588 | 0.8718 | 0.9379 | 0.9000 | 0.9303 |
| Cov. time since last VC financing and VC board seat | -0.0178 | 0.0046 | -0.0169 | 0.0060 | -0.0124 | 0.0100 |
| Cov. share of VC equity and VC board seat | 0.0062 | 0.0092 | 0.0087 | 0.0111 | 0.0064 | 0.0125 |
| Cov. participation and VC board seat | 0.0039 | 0.0205 | 0.0104 | 0.0264 | 0.0064 | 0.0334 |
| Cov. pay-to-play and VC board seat | 0.0048 | 0.0006 | 0.0068 | 0.0006 | 0.0028 | 0.0006 |
| Avg. success rate | 0.0448 | 0.0179 | 0.7334 | 0.7703 | 0.1324 | 0.1172 |
| Cov. time since last VC financing and success rate | -0.0051 | 0.0062 | -0.0165 | 0.0059 | -0.0131 | 0.0282 |
| Cov. share of VC equity and success rate | 0.0063 | 0.0007 | -0.0054 | -0.0041 | 0.0047 | 0.0017 |
| Cov. participation and success rate | 0.0000 | 0.0047 | -0.0100 | -0.0320 | -0.0112 | 0.0096 |
| Cov. pay-to-play and success rate | 0.0087 | -0.0003 | -0.0037 | 0.0038 | 0.0031 | 0.0018 |
| Cov. VC board seat and success rate | 0.0018 | 0.0005 | 0.0065 | -0.0052 | 0.0001 | 0.0028 |

Table A3: Parameter estimates of model modifications: alternative success outcome and contract definitions.

The table describes parameter estimates of model modifications described in Section 6. Panel A describes the estimates of the model where success outcomes are captured by IPO. Panel B describes the estimates of the model where success outcomes are captured by follow-on financing. Panel C describes estimates of the model where missing contract terms are imputed as zeros, provided the VC equity fraction and at least one additional term is non-missing in the data. Significance: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

| | **A. IPO** | | **B. Follow-on financing** | | **B. IPO+Acq.$> 2X$, imputed** | |
|---|---|---|---|---|---|---|
| **Parameter** | Estimate | Standard error | Estimate | Standard error | Estimate | Standard error |
| Distribution of qualities, $a_i$ | 2.4969*** | 0.2793 | 2.5365** | 1.2164 | 2.4542*** | 0.4128 |
| Distribution of qualities, $b_i$ | 3.6123*** | 1.3707 | 3.2592 | 1.9954 | 3.4486*** | 0.9177 |
| Distribution of qualities, $a_e$ | 3.8815*** | 0.8089 | 4.0835*** | 1.3088 | 3.9784*** | 1.0573 |
| Distribution of qualities, $b_e$ | 4.2867*** | 1.4393 | 3.8031** | 1.7177 | 4.1503*** | 1.0985 |
| Frequency of encounters, $\lambda_i$ | 10.6668*** | 3.6094 | 9.7368*** | 3.3911 | 11.3421*** | 3.4474 |
| Frequency of encounters, $\lambda_e$ | 7.3613*** | 2.5486 | 7.5972*** | 1.3963 | 7.4621** | 3.3890 |
| Substitutability of qualities, $\rho$ | -1.3388*** | 0.2334 | -1.3499*** | 0.1295 | -1.3701*** | 0.1800 |
| Probability of success, intercept, $\kappa_0$ | -5.3469*** | 1.9105 | -5.6305 | 5.2213 | -5.3030** | 2.2552 |
| Probability of success, total value, $\kappa_1$ | 0.0970** | 0.0463 | 0.4277 | 0.3872 | 0.1287** | 0.0611 |
| Total value, share of VC equity, $\beta_1$ | 0.7519 | 0.4991 | 0.7621*** | 0.2039 | 0.7887*** | 0.2614 |
| Total value, share of VC equity squared, $\beta_2$ | -2.5241*** | 0.4155 | -2.5783*** | 0.1899 | -2.4584*** | 0.1428 |
| Total value, participation, $\beta_3$ | -0.1529*** | 0.0130 | -0.1513*** | 0.0599 | -0.1512*** | 0.0343 |
| Total value, pay-to-play, $\beta_4$ | 0.0242 | 0.0432 | 0.0210 | 0.0487 | 0.0201 | 0.0230 |
| Total value, VC board seat, $\beta_5$ | -0.0218** | 0.0092 | -0.0207*** | 0.0036 | -0.0206** | 0.0105 |
| Total value, participation × pay-to-play, $\beta_6$ | 0.0170 | 0.0616 | 0.0132 | 0.0782 | 0.0133 | 0.0296 |
| Total value, participation × VC board seat, $\beta_7$ | 0.0346*** | 0.0130 | 0.0341 | 0.0599 | 0.0335 | 0.0343 |
| Total value, pay-to-play × VC board seat, $\beta_8$ | 0.0123 | 0.0723 | 0.0126 | 0.0317 | 0.0122 | 0.0265 |
| Split of value, intercept, $\gamma_1$ | -0.1598* | 0.0896 | -0.2014 | 0.1362 | -0.1919 | 0.1382 |
| Split of value, participation, $\gamma_2$ | -0.1683*** | 0.0343 | -0.1553*** | 0.0594 | -0.1655*** | 0.0374 |
| Split of value, pay-to-play, $\gamma_3$ | 0.0546** | 0.0268 | 0.0520 | 0.0977 | 0.0534* | 0.0315 |
| Split of value, VC board seat, $\gamma_4$ | -0.0385 | 0.0502 | -0.0368*** | 0.0055 | -0.0381* | 0.0203 |
| Split of value, participation × pay-to-play, $\gamma_5$ | 0.0111 | 0.0814 | 0.0106 | 0.0701 | 0.0109 | 0.0261 |
| Split of value, participation × VC board seat, $\gamma_6$ | 0.0256 | 0.0343 | 0.0273 | 0.0594 | 0.0249 | 0.0374 |
| Split of value, pay-to-play × VC board seat, $\gamma_7$ | 0.0105 | 0.1795 | 0.0103 | 0.0594 | 0.0103 | 0.0439 |

Table A4: Parameter estimates of model modifications: industry and deal stage subsamples.

The table describes parameter estimates of model modifications described in Section 6. Panel A describes the estimates of the model using a subsample of deals in the IT industry. Panel B describes the estimates of the model using a subsample of deals in the Healthcare industry. Panel C describes the estimates of the model using a subsample of series A deals. Significance: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

| | **A. IT industry** | | **B. Healthcare industry** | | **C. Series A deals** | |
|---|---|---|---|---|---|---|
| **Parameter** | Estimate | Standard error | Estimate | Standard error | Estimate | Standard error |
| Distribution of qualities, $a_i$ | 2.5473 | | 2.6513 | | 2.4601 | |
| Distribution of qualities, $b_i$ | 3.5330 | | 3.6937 | | 3.4687 | |
| Distribution of qualities, $a_e$ | 3.9142 | | 3.9860 | | 3.9551 | |
| Distribution of qualities, $b_e$ | 4.6245 | | 4.5027 | | 4.1694 | |
| Frequency of encounters, $\lambda_i$ | 13.5944 | | 10.0016 | | 11.1088 | |
| Frequency of encounters, $\lambda_e$ | 10.7644 | | 5.8061 | | 7.0693 | |
| Substitutability of qualities, $\rho$ | -1.2143 | | -1.5565 | | -1.3890 | |
| Probability of success, intercept, $\kappa_0$ | -5.2149 | | -6.6501 | | -5.5069 | |
| Probability of success, total value, $\kappa_1$ | 0.1264 | | 0.1514 | | 0.1322 | |
| Total value, share of VC equity, $\beta_1$ | 0.8294 | | 0.8590 | | 0.7930 | |
| Total value, share of VC equity squared, $\beta_2$ | -2.5138 | | -2.2004 | | -2.4212 | |
| Total value, participation, $\beta_3$ | -0.1506 | | -0.1258 | | -0.1455 | |
| Total value, pay-to-play, $\beta_4$ | 0.0199 | | 0.0140 | | 0.0227 | |
| Total value, VC board seat, $\beta_5$ | -0.0200 | | -0.0186 | | -0.0226 | |
| Total value, participation $\times$ pay-to-play, $\beta_6$ | 0.0158 | | 0.0187 | | 0.0133 | |
| Total value, participation $\times$ VC board seat, $\beta_7$ | 0.0346 | | 0.0337 | | 0.0335 | |
| Total value, pay-to-play $\times$ VC board seat, $\beta_8$ | 0.0134 | | 0.0161 | | 0.0137 | |
| Split of value, intercept, $\gamma_1$ | -0.1772 | | -0.1741 | | -0.1920 | |
| Split of value, participation, $\gamma_2$ | -0.1659 | | -0.1612 | | -0.1658 | |
| Split of value, pay-to-play, $\gamma_3$ | 0.0557 | | 0.0569 | | 0.0535 | |
| Split of value, VC board seat, $\gamma_4$ | -0.0391 | | -0.0415 | | -0.0391 | |
| Split of value, participation $\times$ pay-to-play, $\gamma_5$ | 0.0112 | | 0.0112 | | 0.0109 | |
| Split of value, participation $\times$ VC board seat, $\gamma_6$ | 0.0257 | | 0.0253 | | 0.0274 | |
| Split of value, pay-to-play $\times$ VC board seat, $\gamma_7$ | 0.0108 | | 0.0106 | | 0.0104 | |

Table A5: Parameter estimates of model modifications: time subsamples.

The table describes parameter estimates of model modifications described in Section 6. Panel A describes the estimates of the model using a subsample of deals before 01/01/2007 (the year of introduction of an iPhone). Panel B describes the estimates of the model using a subsample of deals after 01/01/2007. Significance: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

| | **A. Before 01/01/2007** | | **B. After 01/01/2007** | |
|---|---|---|---|---|
| **Parameter** | Estimate | Standard error | Estimate | Standard error |
| Distribution of qualities, $a_i$ | 2.4820 | | 2.9119 | |
| Distribution of qualities, $b_i$ | 3.3866 | | 3.4503 | |
| Distribution of qualities, $a_e$ | 4.0047 | | 4.0949 | |
| Distribution of qualities, $b_e$ | 4.1840 | | 4.1311 | |
| Frequency of encounters, $\lambda_i$ | 11.6282 | | 12.4827 | |
| Frequency of encounters, $\lambda_e$ | 6.0125 | | 13.8099 | |
| Substitutability of qualities, $\rho$ | -1.4954 | | -1.4127 | |
| Probability of success, intercept, $\kappa_0$ | -5.7883 | | -5.6582 | |
| Probability of success, total value, $\kappa_1$ | 0.1290 | | 0.1287 | |
| Total value, share of VC equity, $\beta_1$ | 0.7592 | | 0.7201 | |
| Total value, share of VC equity squared, $\beta_2$ | -2.4146 | | -2.5497 | |
| Total value, participation, $\beta_3$ | -0.1453 | | -0.1537 | |
| Total value, pay-to-play, $\beta_4$ | 0.0220 | | 0.0236 | |
| Total value, VC board seat, $\beta_5$ | -0.0193 | | -0.0234 | |
| Total value, participation × pay-to-play, $\beta_6$ | 0.0154 | | 0.0137 | |
| Total value, participation × VC board seat, $\beta_7$ | 0.0314 | | 0.0297 | |
| Total value, pay-to-play × VC board seat, $\beta_8$ | 0.0141 | | 0.0135 | |
| Split of value, intercept, $\gamma_1$ | -0.1602 | | -0.2025 | |
| Split of value, participation, $\gamma_2$ | -0.1625 | | -0.1633 | |
| Split of value, pay-to-play, $\gamma_3$ | 0.0560 | | 0.0548 | |
| Split of value, VC board seat, $\gamma_4$ | -0.0361 | | -0.0386 | |
| Split of value, participation × pay-to-play, $\gamma_5$ | 0.0112 | | 0.0112 | |
| Split of value, participation × VC board seat, $\gamma_6$ | 0.0257 | | 0.0236 | |
| Split of value, pay-to-play × VC board seat, $\gamma_7$ | 0.0106 | | 0.0106 | |

Table A6: Parameter estimates of model modifications: alternative theoretical assumptions.

The table describes parameter estimates of model modifications described in Section 6. Panel A describes the estimates of the model where the annual discount rate for the agents is 20%. Panel B describes the estimates of the model where entrepreneurs are overconfident (the overconfidence parameter is 25%). Panel C describes estimates of the model where firm values are affected by a match-specific shock. Significance: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

| | **A. High discount rate** | | **B. Ent. overconfidence** | | **C. Match-specific shocks** | |
|---|---|---|---|---|---|---|
| **Parameter** | Estimate | Standard error | Estimate | Standard error | Estimate | Standard error |
| Distribution of qualities, $a_i$ | 2.6884 | | | | | |
| Distribution of qualities, $b_i$ | 3.5008 | | | | | |
| Distribution of qualities, $a_e$ | 3.1557 | | | | | |
| Distribution of qualities, $b_e$ | 4.1972 | | | | | |
| Frequency of encounters, $\lambda_i$ | 9.9214 | | | | | |
| Frequency of encounters, $\lambda_e$ | 9.7260 | | | | | |
| Substitutability of qualities, $\rho$ | -1.4390 | | | | | |
| Probability of success, intercept, $\kappa_0$ | -5.5431 | | | | | |
| Probability of success, total value, $\kappa_1$ | 0.1343 | | | | | |
| Total value, share of VC equity, $\beta_1$ | 0.7681 | | | | | |
| Total value, share of VC equity squared, $\beta_2$ | -2.4785 | | | | | |
| Total value, participation, $\beta_3$ | -0.1489 | | | | | |
| Total value, pay-to-play, $\beta_4$ | 0.0192 | | | | | |
| Total value, VC board seat, $\beta_5$ | -0.0203 | | | | | |
| Total value, participation × pay-to-play, $\beta_6$ | 0.0135 | | | | | |
| Total value, participation × VC board seat, $\beta_7$ | 0.0366 | | | | | |
| Total value, pay-to-play × VC board seat, $\beta_8$ | 0.0122 | | | | | |
| Split of value, intercept, $\gamma_1$ | -0.1823 | | | | | |
| Split of value, participation, $\gamma_2$ | -0.1591 | | | | | |
| Split of value, pay-to-play, $\gamma_3$ | 0.0559 | | | | | |
| Split of value, VC board seat, $\gamma_4$ | -0.0402 | | | | | |
| Split of value, participation × pay-to-play, $\gamma_5$ | 0.0110 | | | | | |
| Split of value, participation × VC board seat, $\gamma_6$ | 0.0262 | | | | | |
| Split of value, pay-to-play × VC board seat, $\gamma_7$ | 0.0104 | | | | | |
| Entrepreneur overconfidence (fixed) | – | – | 25% | – | – | – |
| St.dev. of match-specific shock, $\sigma$ | – | – | – | – | | |