Venture Capital Contracts

June 2018

Abstract

We develop a dynamic search and matching model to estimate the impact of venture capital contract terms on startup outcomes and the split of value between entrepreneur and investor in the presence of endogenous selection. Using a new data set of over 10,000 first financing rounds of startup companies, we estimate an internally optimal equity split between investor and entrepreneur that maximizes the probability of success. However, in almost all deals, investors receive more equity than is optimal for the company. In contrast to most theoretical predictions, participation rights and investor board seats reduce company value, while shifting more of it to the investors. Eliminating these terms increases startup values through rematching, making entrepreneurs better off and leaving all but the highest quality investors marginally worse off.

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. Startup 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). The theoretical literature explains the complicated contracts between entrepreneurs and venture capitalists (VCs) that arise in practice, by the improved incentives and information sharing that they engender, typically assuming that investors are homogeneous and competitive, and thus earn zero profit (Cornelli and Yosha, 2003; Kaplan and Strömberg, 2003; Schmidt, 2003; Repullo and Suarez, 2004; **?**).

A contrasting view is that investors negotiate for certain contract terms not to grow the size of the pie that is divided between the contracting parties, but mainly to change the distribution of the pie in their favor. This is possible because venture capitalists (VCs) are not homogeneous. Some VCs are of higher quality (a shorthand for their experience, network, and other value-added activities) than others, and a lesser quality VC 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 startup 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 wield greater 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 value overall, at the expense of the entrepreneur, who experiences poor returns (e.g., Moskowitz and Vissing-Jørgensen, 2002; Kaplan and Strömberg, 2004; 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 in addressing this question 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 startups, 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). 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.[1]

The second main problem is that startup contracts are private, and data is difficult to find. To take the model to the data, we collect a new data set that contains more than 10,000 first-round VC financings, of which nearly 5,000 have detailed contract data. 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 startup'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 the following results. First, there is an internal optimal equity share that maximizes the startup's probability of a successful exit, 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., Schmidt, 2003; Inderst and Müller, 2004; Casamatta, 2003; Hellmann, 2006). Second, both participating preferred stock and VC board seats lower the chance of success, while transferring a larger fraction of the startup's value to the VC. The traditional view that participation makes the entrepreneur exert more effort, may be offset by, e.g., asset substitution incentives from the debt-like features of participation rights or preferences for window-dressing. The value creation aspects of investor board representation due to improved governance and monitoring may be offset by reduced incentives for the entrepreneur to exert effort because they have less ownership and control over key decisions. Third, pay-to-play increases the chance of success, while leaving a larger fraction of the value with the entrepreneur. If the VC chooses not to participate in a subsequent round of financing, the pay-to-play term returns cash flow and/or control rights to the entrepreneur, whose incentives to exert effort may, in turn, be increased.

Despite their value-reducing impact, the VC benefits from participation and board seats because the VC receives a larger share of the value, which on balance increases the VC's expected payoff. The first-best contract that maximizes the startup's value gives the VC an equity share of 7.0% and pay-to-play but no participation or board seats; however, due to the other pervasive

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

contractual features, the VC actually receives 24% of the startup's value. In the average observed deal, the startup's value is only 82% of the first-best value, but the VC gets 45% of the value.

We estimate important trade-offs between the cash flow and control rights of the contract, as a function of investor and entrepreneur quality. Entrepreneurs (VCs) match with a range of VCs (entrepreneurs) between an upper and lower threshold, forming blocks. While these ranges are generally increasing in the entrepreneur's (VC's) quality, endogenous contracting introduces exceptions to this rule, implying that the assumption of 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 encounters and matches with a higher quality VC, the pay-to-play term is dropped and VC's equity share rises, up to a point where the VC has enough bargaining power to negotiate for 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 startup'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, the equity share rises again, to a point where the VC asks for participation rights. This is offset by the VC giving up its board representation and taking a smaller equity stake.When entrepreneurs match with the very best VCs they can hope to pair up with, the VC gets both participation and board seats.

One limitation of our approach is that we cannot make statements about the impact on value of terms that are always present. However, we can estimate the joint effect of these terms on the value split. Overall, we find that they transfer an additional fraction of the company's value to the VC. However, since the terms are always present and thus not likely to be very contentious, it is not clear whether the entrepreneur is worse off under these terms. These terms may in fact increase the startup's value, such that both VC and entrepreneur benefit.

We explore the effects of eliminating the possibility of using participation and board seat contract terms. The immediate effect is that more value shifts towards entrepreneurs, negatively affecting VCs. If we keep matches the same, the effect on firm values is negative but small. This effects become positive if we allow market participants to rematch, and it is most pronounced for low quality entrepreneurs. They are able to match with higher-quality VCs and at higher rates as their bargaining power has increased, because they no longer have to accept participation and investor board seats. In the aggregate, due to both higher average firm value and higher matching rates, the value of all deals in the market rises by 4.7%. Finally, we explore the effects of decreasing search frictions in the market. Surprisingly, the effect on the value of all deals in the market is negative: for example, if the expected time between encounters is cut in half, this value decreases by 2.1%. If VCs are able to meet new entrepreneurs more frequently, they wield even more bargaining power and claim a higher fraction of the company's value. 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 characteristics on the firm value. In addition, endogenous contracting allows us 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.

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 startups at more investor-friendly terms, consistent with our results. Cumming (2008) uses a sample of 223 investments in European VC-backed startups 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. Bengtsson and Bernhardt (2014) show that venture capital firms exhibit "style" in their contracts, recycling them over multiple startups. 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. They 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 (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 sensitivities of valuations to contract terms. However, they cannot determine the impact of control contract 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. We also do not require 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 existence of a search equilibrium and positively assortative matching in a continuous-time model with a single class of agents encountering each other. In our paper, endogenous contracting implies that generally, conditions for a positively assortative matching do not hold even when entrepreneur and VC types, given a contract, are complements. We do not find that positive assortative matching holds in equilibrium under estimated model parameters. Adachi (2007) models the marriage market with two classes of agents (males and females) 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 a 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.

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

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

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, π, 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		$\pi = 4.39$ $c^* = 0.13$	$\pi = 5.11$ $c^* = 0.23$
	2		$\pi = 2.51$ $c^* = 0.19$	$\pi = 2.92$ $c^* = 0.29$
	1	$\pi = 0.58$ $c^* = 0.21$	$\pi = 0.74$ $c^* = 0.4$	

If we could collect a data set of i, e, c^*, and π 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 π[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

[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.

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 π for each match, we therefore take a more feasible approach and recover aggregate distributions of i, e, and π 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 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]

[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.

[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.

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 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 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 λ_i. Similarly, each entrepreneur randomly encounters an investor from the population of investors according to a Poisson process with positive intensity λ_e.[6] 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[7], 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.[8] 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 an entrepreneur 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

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

It is convenient to think of π as the expected present value of all future cash flows generated by the start-up, including the exit value. This value is affected by types of counterparties as well as the contract they sign through the continuous and bounded function $h(c)$. The counterparties

[6]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.

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

[8]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 liquidation preference, then $C \equiv [0, 1] \times \{0, 1\}$: the second dimension of the contract space captures the absence or presence of the 1X liquidation preference term. As we will see in the data, in first-stage financings, the counterparties rarely choose a different liquidation preference multiplier.

receive instantaneous 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 effective 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.[9]

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 in-

[9]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 only become relevant again when we examine the present value of all potential deals in the market in Sections 5 and 6.

vestor's offer. Third, with probability $1 - \lambda_i dt$, the investor may not encounter an entrepreneur 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*

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

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

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. Contract terms impact the expected value of a start-up and its split between investor and entrepreneur 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, first, 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.[10] On the contrary, our findings on which contract terms impact values can inform about which mechanisms previously considered in the theoretical literature are likely important in practice. Second, by considering the impact 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

[10] 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.

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 U.S.-headquartered start-up company financing rounds between 2002 and 2015, collected from the Dow Jones VentureSource database. Although the sample of financings ends in 2015, we have information on exit events through June of 2017. These additional two years provide time for startups to exit and realize outcomes. We augment the Dow Jones 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, either electronically or in person, and encode the key venture capital contract terms from prior financing rounds described in those documents.[11]

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.[12] Other early-stage investors, such as friends and family, angels, or incubators, may have objectives other than profit-maximization. Although 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 by years since first investment

[11] 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.

[12] Financings rounds greater than $100 are also excluded as they are more likely to be non-VC-backed startups.

by the time of financing. Our final filter limits the sample to rounds that involve the sale of common or preferred equity, the predominant form of VC securities. This filter thus excludes debt financings such as loans and convertible notes that have no immediate impact on equity stakes, or small financings through accelerators or government grants. We lose 11% of first round financings through this exclusion. We apply the above filters after collecting contract data from all articles of incorporation, including restatements filed after later financing rounds, as supplemental first-round contract terms can sometimes be identified from such refilings.

3.1 Descriptive Statistics

The sample consists of 10,967 first financing rounds of start-up companies, involving 1,998 unique investors. Table I provides variable definitions, and Table II reports summary statistics. Panel A of Table II reveals that at the time of financing, the average (median) start-up is 1.8 years (1.25 years) old, measured from the date of incorporation. Most start-ups are in the information technology industry (47% of firms), followed by healthcare (19%). 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 0.8 (0.3) years. For 1,745 rounds (16% of the sample), the VC is a first-time lead (but may have been a non-lead investor before) and we cannot calculate the time since last lead financing. These deals tend to be smaller, but otherwise do not appear to be systematically different from the deals for which the time since last lead financing is known (results not reported).

In the average (median) round, 2.4 (2) financiers invest $5.2 million ($2.7 million) in the firm at a post-money valuation of $18.5 million ($10.8 million), where both amounts are in 2009 dollars. Post-money is the valuation proxy of the start-up after the capital infusion, which is calculated in a straightforward manner from the investors' equity share.[13] The post-money valuation is usually interpreted as the market value of the firm at the time of financing (π 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. However, in virtually all cases in our sample (95%), 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 inter-

[13]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. Note that this computation does not take into account, e.g., value of convertibility of VC shares.

ested in the impact of contract terms on valuation, the post-money valuation would be a poor metric to use, and we use exit outcomes instead (discussed below). AK: ALSO, POST-MONEY ASSUMES NO BARGAINING POWER OF THE VC (SEE HELLMAN (2002) AND INDERST AND MUELLER (2004)) But these 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 1,938 deals for our sample period, mostly gathered from IPO filings of successful firms. Our additional data collection efforts provide another 4,085 observations, resulting in a more complete and balanced sample of 6,023 equity stakes. Panel B of Table II shows that the average (median) share sold is 35% (32%), ranging from 22% at the first quartile to 46% at the third quartile.

Contract terms beyond the equity share 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 1,534 and 4,561 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 5,176 deals with some contract data beyond equity shares on first financing rounds alone (across all rounds the data contain over 21,000 contracts). 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 3% 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 41% 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. A rarely used full ratchet anti-dilution rights term in our data (1%) 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 10% of financings have entrepreneur-friendly pay-to-play requirements. These terms punish investors that do not reinvest in future financings. Finally, 35% of financings have redemption rights. The latter gives the holder of the security the option to call their capital back from the startup after 3-5 years. If a startup 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 62% of lead investors in our sample have a board seat at the time of the first investment.

Panel C of Table II summarizes the exit outcomes. We follow financings through 2009 to allow time for our three exit outcomes: an initial public offering (IPO), acquisition or failure. Some firms have yet to exit by the end of the exit tracking period (June 2017) and are thus still private. The table first shows that 4% of startups exit via an initial public offering.[14] Acquisitions are more common at 40%, however, many of these exits are hidden failures (e.g., Puri and Zarutskie, 2012). To separate out high- and low-quality acquisitions, we thus use the reported exit valuations if available. Exit valuations are almost universally available for IPOs and for a subset of typically successful acquisitions. With these data, we create a variable "IPO or Acq. $> 2X$ capital" that equals to one if the start-up had an IPO or had an acquisition at a private at least two times total capital raised. The outcome "Out of business" characterizes whether a startup shut down or went into bankruptcy. It appears to be low at 17%, however, this is because of both the aforementioned hidden failures in acquisitions and the fact that many firms that are still private and in fact failed firms. We find that 16% have either an IPO or successful acquisition. Over one third of start-ups (38%) are still private.

3.1.1 Sample Selection

Revelation of contract terms is non-random. For example, start-ups that eventually achieve a public offering are required to disclose past financing round details, and large, successful start-ups are more likely to reveal their financing valuations while private. Contract data must be actively collected by the data providers Pitchbook and VC Experts, and the data suggests their sampling is non-random. Table III presents summary statistics for the sample of financings with and without contract data. The panel "Deals with contract data" considers the set of financings with at least

[14] The rate falls to 2% if we consider first-financings in the full sample period 2002 to 2015.

one, in addition to equity split, observable contract feature discussed above. The panel "All deals" considers the full sample as described in Table II. As before, exit outcomes are only defined for financings before 2010.

There are few differences between financings with contracts and the full sample in terms of firm age, industry or syndicate size. Financings with contract data tend to raise more capital ($7.8 vs. $5.2) and occur earlier in our sample period (2008 vs. 2009). According to the outcome data, financings with contract information also exhibit higher success rates. These financings have lower failure rates (12% vs. 17%) and higher rates of both IPOs (10% vs. 4%) and high quality exits (23% vs. 16%). Overall, the sub-sample of financings with at least some observable contract terms likely represents a positive selection of the underlying population: high-quality startups and high-quality investors. Any resulting bias for the results below is unclear, however, it is important to note that nearly all previous studies using investment-level returns or contracts face similar issues. However, given that our data represents the largest set of both valuation and contracts data, we believe any selection issues are relatively smaller in our sample.

4 Results

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

4.1 Correlations

Table IV presents the correlations and covariances for the set of contract, outcome, and VC activity variables. The upper-right triangle of the table first shows that the share of investor equity is positively correlated with other contract terms and successful outcomes. For example, the use of the participating preference term is positively correlated (28%) with the share of investor equity, while more investor control through board seats exhibits a similar relationship (20%). The correlations between contract terms such as cumulative dividends, liquidation preference, and redemption are also positive. Positive correlations across all contract terms can arise, first, if all terms are value-creating and thus are, optimally, complements in a typical financing. Alternatively, at least some contract terms may not be value-creating and simply transfer value between counter-parties, and may thus be substitutes. However, in the sample of deals, we may still observe positive correlations among such terms because counter-parties select each other non-randomly. Our estimation is designed to differentiate between these two explanations. Finally, all contract terms positively correlate with our two success measures (the last two columns). As before, one has to be careful with interpreting these correlations, as they are insufficient to separate the effects of contract value creation and selection on success.

Table V complements the table of pairwise correlations and covariances by presenting simple OLS regressions of startup financing valuations (post-money) and outcomes on contract terms. Columns 1–4 consider the log of the post-money valuations and columns 5–8 consider our main outcome variable, the IPO indicator, each regressed on four major contract terms. All regressions include fixed effects for financing year, startup founding year, industry and startup headquarters state. We also introduce the squared value of the equity sold to the investor.[15] The results reveal a U-shaped relationship between equity share and outcomes across all specifications and outcome variables. This result is counterintuitive as it suggests that there is an equity share between 0% and 100% that minimizes the value or probability of success, in contrast to the hump-shaped relation predicted by double moral hazard models. With respect to the other contract terms, pay-to-play and VC board seats correlate with higher valuations and IPO success rates, and participation correlates with lower outcomes. 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 25 point grid.[16] 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 choose flexible functional forms for the impact of contract terms on firm value and its split,

$$h(c^*) = \exp\left\{\beta_1 c_1^* + \beta_2 c_1^{*2} + \beta'_{3:D+1}(1 - c_1^*)c_{2:D}^*\right\}, \tag{10}$$

$$1 - \alpha(c^*) = (1 - c_1^*)\exp\left\{\gamma'_{1:D}(1 - c_1^*)(1 \quad c_{2:D}^*)\right\}, \tag{11}$$

where $D = \dim\{C\}$ is dimensionality of the contract space. In principle, contact terms entering

[15] Sample sizes differ across specifications for two reasons. First, some financings only have a subset of contract terms available. Second, the first four columns use financings over the full sample period, while those with the IPO dependent variable consider financings between 2002 and 2009.

[16] A finer grid delivers very similar outcomes but results in a substantial computational slowdown. 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.

the functional forms can be generic. However, we pay special attention to the fraction of equity retained by the investor, c_1^*[17], 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 (10). Theory suggests that there can 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 (10) 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 $1 - c_1^*$, because other terms become increasingly less meaningful as the investor owns a larger fraction of the company. For example, in the extreme case of 100% equity ownership by the investor, there is no incremental role for investor downside protections and other contract terms such as board seats. Finally, the exponential function prevents valuations from being negative.

Turning to the value split in equation (11), 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 $1 - c_1^*$, because the impact of other terms on the value split is more important when the investor owns a smaller fraction of the company, while the value split converges to a common equity split when the investor owns a large fraction. In the example of 100% ownership by the investor, the existence of liquidation preferences or other downside protections for the investor is irrelevant, as the investor owns all of the firm and therefore gets all the value regardless. Most contract terms are downside protections for the investor, such as participation and liquidity preferences, 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 γ coefficients in equation (11) are less than or equal to zero (but we do not enforce this condition in the estimation). The functional form of equation (11) then ensures that $\alpha(c^*) \in [c_1^*, 1]$. The intercept, γ_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 preferences are nearly always equal to one in our sample of first-round financings.

Since π is not observed, to take the model to the data we add an outcome equation that captures the probability of an initial public offering. This is the traditional success measure used in the venture capital literature, because true valuations are not observed and cannot be

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

easily recovered from post-money valuations, as explained in Section 3.1.[18] We use a probit-type specification and define the latent variable

$$Z(i, e, c^*) = \kappa_0 + \kappa_1 \cdot \pi(i, e, c^*) + \eta, \tag{12}$$

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

$$Pr(IPO = 1|i, e, c^*) = \Phi(\kappa_0 + \kappa_1 \cdot \pi(i, e, c^*)), \tag{13}$$

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

We use GMM with the efficient weighting matrix to estimate the main parameters of interest, $\theta = (\lambda_i, \lambda_e, a_i, b_i, a_e, b_e, \beta, \gamma, \kappa)$. For each θ and for each combination of investor and entrepreneur quality, the model produces the set of equilibrium contract terms, $c^*(i, e; \theta)$, and the probability of an initial public offering, $Pr(IPO = 1|i, e, c^*; \theta)$. Additionally, for each investor, the model produces the distribution of time since last first-round financing, τ. 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. 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 23 moments and 23 parameters to estimate.[20] The model is just

[18]In robustness checks, we also use the probability of an IPO or high-quality ($> 2X$ capital) acquisition.

[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.

[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 γ_1. Among the remaining terms, the ex-ante least important, despite its frequent occurrence, is redemption. This term appears only relevant in an ex-ante unlikely case when an investor 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 investor can trigger its redemption rights; however, upon this event, often the entrepreneur does not have the liquidity to buy out the investor. 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 third moment of the VC equity share, the most variable term, to the set of moments allows us to add cumulative dividends to the set of terms; we present the results of this computationally-intensive extension in Section 6.

identified.

4.2.2 Estimates

For IPO and follow-on financing outcome variables, Table VI compares theoretical moments computed at estimated parameter values to empirical moments. The model cannot match uninformative IPO moments, in an attempt to do so tilting other moments. Hence even first moments of participation and VC board seat terms, as well as the probability of an IPO are far from their empirical counterparts. In contrast, the model matches well more informative follow-on financing moments, resulting in a better overall fit.[21] For this reason, in the remainder of the paper we select the model that uses the follow-on financing outcome variable as our main model.

Table VII shows parameter estimates and their standard errors. In the remainder of the section, we discuss economic magnitudes and the intuition behind these parameters.[22] 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) is maximized. The entire value-maximizing contract is $c^{Max} = (0.132, 0, 1, 0)$: 13.2% of VC equity, no participation or VC board seats, and the inclusion of pay-to-play.[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. VCs and entrepreneurs tend to cluster in *blocks* (e.g., better VCs usually match with better entrepreneurs), but not always: sometimes, sufficiently low-quality VCs attract high-quality entrepreneurs by offering them good terms.[24] The average VC equity share across all feasible deals is 31.9%. The entire representative contract, in which each term is equal to the average of the term across all feasible deals is $c^{*,Avg} = (0.319, 0, 0, 1)$. The worst VCs in a block

[21] While the test of overidentifying restrictions is not possible in a just identified model, the fit is, visually, sensible.

[22] The impact of pay-to-play and VC board seats (in the absence of other terms) on the firm value appears to be insignificant. The GMM objective function is very sensitive to all parameters; however, because we have to discretize the model to estimate it, it is similarly sensitive to pairs of parameters measuring the impact of a term on the total value and its split, resulting in multicollinearity. This problem is typically solved by fixing (or, in linear probability models, setting equal to zero) one of the two parameters. We apply economic reasoning and note that it is arguably easy to write a theoretical model of a value-maximizing VC who uses participation and VC board seats to increase its share of the firm, while pay-to-play is used to decrease its share; it is more difficult to write a model with the opposite predictions. Therefore if we solve the multicollinearity problem by fixing participation and VC board seat (pay-to-play) parameters in the split of value equation at reasonable negative (positive) values (e.g., at estimated values), we would in fact obtain a significant negative impact of the VC board seat on the firm value in the absence of other terms (std. err = 0.0054 if the outcome variable is follow-on financing).

[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] While this result is important because it implies that positively assortative matching does not necessarily hold in settings with endogenous contracts (and therefore should not be assumed), it is somewhat tangential to our main narrative, and is discussed in detail in Appendix E.

use pay-to-play. Because $\hat{\beta}_4 > 0$ and $\hat{\gamma}_3 > 0$ in Table VII, the term is beneficial for entrepreneurs and the total value. Better VCs fade out pay-to-play and eventually replace it with VC board seats. Because $\hat{\beta}_5 < 0$ and $\hat{\gamma}_4 < 0$ in Table VII, in the absence of other terms VC board seats are beneficial for VCs but detrimental to the total value. The best VCs in the block additionally include participation. Because $\hat{\beta}_3 < 0$ and $\hat{\gamma}_2 < 0$ in Table VII, and the effects are large, this term is rather beneficial for VCs but detrimental to the total value. Only the best VCs enjoy enough bargaining power to offer participation without the risk of driving entrepreneurs away. For the same reason, such VCs also retain a higher-than-average VC equity share, 33.4%, which is an unconstrained maximizer of $\pi_i(i, e, c)$. Interestingly, because $\hat{\beta}_5 + \hat{\beta}_7 > 0$ and $\hat{\gamma}_4 + \hat{\gamma}_6 > 0$, in the presence of participation VC board seats become beneficial for both parties and, in turn, the total value. The best VCs retain this term to soften the entrepreneur-unfriendly impact of participation. The entire unconstrained contract that the best VCs offer is $c^{*,Unc} = (0.334, 1, 0, 1)$. 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 combination of VC and entrepreneur qualities, in the left panel of Figure 2, we 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 for combinations of terms that occur in equilibrium. For example, a deal with the average contract $c^{*,Avg}$ achieves 88.3% of the maximal total value. A deal signed by the best VCs in a block with the unconstrained contract $c^{*,Unc}$ performs worse and achieves only 80.4% of the maximal value.

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.,

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 been always included. Instead, this term is absent in 12% 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.

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 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]Another possibility is that the impact of VC board seats is VC quality-dependent: worse (better) VCs destroy (create) value by interfering with the firm's activities. In this case, if participation is a term offered by better VCs, control by such VCs is valuable and captured by a positive impact on the value of the interaction term between participation and the VC board seat.

Across all deals, we have a positive correlation between these two terms. Participating convertible 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]

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 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. Even when the contract is common convertible equity, VCs retain a substantially 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 $\hat{\gamma}_1 < 0$ in Table VII. In particular, while 13.2% of VC equity in the value-maximizing contract c^{Max} may appear low, this contract, in fact, leaves the VC with 34.2% of the total value. The presence of participation and the VC board seat further increases the VC fraction of the firm. For example, the deal with the average contract $c^{*,Avg}$ leaves the VC with 48.2% of the total value. A deal signed by the best VCs in a block with the unconstrained contract $c^{*,Unc}$ leaves the VC with 53.4% 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 choose $c^{*,Unc} = (0.334, 1, 0, 1)$, the post-money valuation of their firm, per dollar of capital invested, would be \$1/0.334 = \$2.99. In contrast, because the best VCs retain 53.4% of the total value, the modified valuation would instead be \$1/0.503 = \$1.87, a 37.5% decrease compared to the post-money valuation. In large first-round financings by such VCs, the difference between valuations can reach millions of dollars.

Panel A of Table VIII provides additional detail on the total value and its split across deals completed by different quartiles of VC and entrepreneur qualities. Deals completed by high-quality VCs are, on average, twice as large as deals completed low-quality VCs. Low-quality entrepreneurs are effectively driven off the market (although they do sign deals very rarely) and there is substantially more heterogeneity in the total value as a function of entrepreneur quality than VC quality: most high-value deals are signed by high-quality entrepreneurs. The VC share

[28] Lastly, it is worth mentioning that our model produces persistent contracts for a given VC: no matter the entrepreneur quality, the VC offers approximately the same contract within a block. 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.

of the total value increases with its quality and decreases with entrepreneur quality.

Returning to coefficient estimates, frequencies of VC and entrepreneur encounters suggest that a VC meets a entrepreneur of a sufficiently high quality, on average, every $1/\hat{\lambda}_i = 41$ days, while such an entrepreneur meets a VC, on average, every $1/\hat{\lambda}_e = 46$ days. Panel B of Table VIII shows that these frequencies of encounters, combined with less interpretable estimates of quality distributions, result in VCs (entrepreneurs) signing deals, on average, every $1/1.366 = 267$ ($1/1.228 = 297$) days. Low-quality VCs are the most active: bottom 25% of VCs by quality sign a deal, on average, every 229 days, while top 25% sign a deal every 283 days. In contrast, low-quality entrepreneurs rarely sign a deal, while top 25% of entrepreneurs by quality sign a deal, on average, in 79 days.

Panel C of Table VIII 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 VIII shows that overall, VCs retain 76.94% of the present value of all deals in the market. Bottom 25% of VCs by quality retain 12.61% of this value, while top 25% retain 24.87%. In contrast, bottom 25% of entrepreneurs by quality retain almost no value, while top 25% retain 18.15%. 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.

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).

[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.

5.1 Contractual Features

The naive approach to examine the effect of a removal of contractual features on deals would be to simply remove features in each deal, in which they are present, 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 IX 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. In Table A1 in the appendix, we also analyze the effect in deals by high- and low-quality VCs and entrepreneurs. 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 IX 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 0.11% decrease in the total value. In the absence of market effects, the VC replaces removed VC-friendly features with other VC-friendly terms. These terms are more detrimental to the total value and the VC share of it than removed features, decreasing both post-regulation.

In contrast, the average effect of rematching due to a removal of VC-friendly features is positive. For example, if contractual features implemented by participation are removed, the aggregate equilibrium effect is a 1.82% increase in the total value, implying that rematching results in a 1.93% increase. As for the split of value, the aggregate equilibrium effect is a 0.95% decrease (2.77% increase) in the VC's (entrepreneur's) value, implying that rematching results in a 0.84% decrease (2.77% increase). Interestingly, the average effect of rematching due to a removal of entrepreneur-friendly features is still positive. The reason is that sufficiently low-quality investors may combine pay-to-play with VC board seats, which in this contract are value-decreasing. The removal of pay-to-play means that to retain entrepreneurs, such investors also have to give up board seats, resulting in an overall positive impact on the value. If contractual features implemented by pay-to-play are removed, the aggregate equilibrium effect is a 1.88% decrease in the total value, implying that rematching results in a 1.85% decrease. As for the split of value, the aggregate equilibrium effect is a 0.48% decrease (1.40% decrease) of the VC's (entrepreneur's) value, implying that rematching alone results in a 0.45% decrease (1.40% decrease).

While the average aggregate equilibrium effect is modest, it changes dramatically across deals. Table A1 in the appendix shows that if VC-friendly contractual features are removed, deals by low-quality VCs decrease in value, and the low-quality VC value is lower than the average VC value across all deals. At the same time, deals by low-quality entrepreneurs substantially increase in value, and such entrepreneurs disproportionately benefit. Interestingly, similar patterns but on a smaller scale appear if entrepreneur-friendly features are removed.

Panel B of Table IX shows the effect of a removal of contractual features on deal frequencies. For example, if contractual features implemented by both participation and VC board seat are removed, deals, on average, become 4.33% more frequent. Table A1 in the appendix shows that this increase is mainly affected by low-quality investors and entrepreneurs, who make substantially more deals. At the same time, high-quality entrepreneurs match less frequently. Again, similar patterns appear if entrepreneur-friendly features are removed.

The intuition behind these results is as follows. In equilibrium, VC- (entrepreneur-) friendly features are offered by the best (worst) VCs in a block. A removal of VC-friendly features, despite rebalancing of remaining terms, leads to lower continuation values $V_i(i)$ for the best overall VCs and higher continuation values $V_e(e)$ for entrepreneurs who match with them. Such entrepreneurs thus become more selective in their deals and stop matching with the worst VCs in their block. This leads to lower continuation values for the worst VCs in the block, who have to match with worse entrepreneurs. The rematching effect snowballs in this manner down the ladder of VC and entrepreneur qualities, resulting in the VCs (entrepreneurs) losing out (winning out). The biggest winners are the lowest-quality entrepreneurs, who rarely matched before but see a dramatic increase in their match rates with the lowest-quality VCs. In contrast, a removal of entrepreneur-friendly features directly leads to lower continuation values for the worst VCs in the block, who are unable to provide acceptable terms to entrepreneurs previously matched with them, and hence start matching with worse entrepreneurs. This leads to lower continuation values of entrepreneurs who previously matched with such VCs. This rematching effect snowballs in this manner down the ladder of qualities, resulting in *both* the VCs and entrepreneurs losing out, and less valuable deals overall. The only winners are still the lowest-quality entrepreneurs, who match more frequently.

Panel C of Table IX combines the effect of a removal of contractual features on deal values and deal frequencies into the effect on the expected present value of all deals in the market. The effect is expressed in the percentage of the estimated expected present value of all deals. The effect is always positive and large: for example, it is 4.73% when features implemented by both participation and the VC board seat are removed, while VCs (entrepreneurs) on average lose 1.16% (gain 5.89%). Table A1 in the appendix shows that high-quality entrepreneurs (low-quality VCs) disproportionately benefit (suffer). An increase in the expected present value of all deals due to a removal of entrepreneur-friendly features implemented by pay-to-play may appear counterintuitive. However, recall that the present value combines deal values, which in this case, on average, decrease, with deal frequencies, which, on average, increase, overcoming the deal value effect.

The high heterogeneity of the equilibrium effect across deals and its impact on the size of the VC market suggest that selection of parties into deals is key. A removal of VC-friendly features leads to substantial value creation and decreases 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-dipping" implemented by participation). A caveat is that while we consider a general equilibrium in the VC market, agents may have other options away from the market and can leave, or additional agents can enter in the new equilibrium. Again, 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 λ_i and λ_e by a factor of 2, 5, and 10.

Table X shows that low search frictions do not necessarily increase the size of the VC market. The effect is expressed in the percentage of the estimated expected present value of all deals. A moderate decrease in frictions ($2X$) leads to a 2.13% decrease in the expected present value of all deals. Entrepreneurs (VCs) on average lose 7.18% (gain 5.05%). Table A2 in the appendix shows that high-quality entrepreneurs (VCs) suffer (benefit) the most. The transfer of value is more severe when a decrease in costs is substantial ($10X$). It leads to a 1.75% decrease in the expected present value of all deals. Entrepreneurs (VCs) lose 16.21% (gain 14.46%).

The intuition behind this result is as follows. The estimated distribution of entrepreneur qualities, $F_e(e)$, is tilted towards lower qualities. VCs, who matched with a wide range of entrepreneurs, thus benefit from dropping their worst matches, which occur frequently, and waiting less for better entrepreneurs and offering them more VC-friendly contracts in the new equilibrium. This effect is particularly strong for the best overall VCs, who only match with best overall entrepreneurs. In contrast, the estimated distribution of VC qualities, $F_i(i)$, is tilted towards higher qualities.

Entrepreneurs thus benefit less from dropping their worst matches, which are infrequent, and lack the ability to offer contracts. However, they are excluded from their best matches by VCs, ending up with worse deals in the new equilibrium. This effect is particularly strong for high-quality but not best overall entrepreneurs, who are excluded from matches with the best overall VCs.

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]

6 Robustness and Extensions

Our results are robust to various model modifications and extensions. In particular, (a) complementarities between deal parties may not be captured well by the product of their qualities, calling for a more flexible model of the deal value; (b) VCs and entrepreneurs may be overconfident; (c) capital raised by an entrepreneur may be yet another endogenous contract term; (d) the VC market before and after the crisis (or before and after the major structural tech change around the release of iPhone) may be structurally different; (e) entrepreneurs may wield additional bargaining power in contract negotiations; (f) different submarkets (e.g., different geographical locations and industries) may have different distributions of agents' qualities; (g) parties may have higher risk aversion (higher r); (h) when using the IPO outcome variable, contract data in 2009–2015 may still be useful even though IPOs for many such firms are unlikely to occur before 2015; (i) a finer 51 point grid of VC and entrepreneur qualities may give more precise estimates; (j) a non-optimal GMM weighting matrix (i.e., diagonal) may better match first moments of deal outcomes. Appendix F contains discussion of (a)–(f); other robustness results are available upon request.

Two additional extensions can be of interest. First, in practice, VCs consider multiple entrepreneurs at once, 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 coun-

[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 λ_i and λ_e are high, our model converges to a static matching model. Direct estimation of the model when λ_i and λ_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 applied to the next encounter is close to one. However, since the value is split very differently between 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.

terparties' qualities that an agent has to simultaneously consider in the first case, and 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 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 startup 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 data set of over 10,000 first financing rounds, we estimate an internally optimal equity split between investor and entrepreneur that maximizes the probability of success. however, in virtually all deals, investors receive more equity than is optimal for the startup. Participation rights and investor board seats reduce company value, in contrast to most theoretical predictions, while shifting more of the startup's value to the investors. Eliminating these terms increases startup values through rematching, making entrepreneurs better off and leaving all but the highest quality investors marginally worse off. Our results suggest that selection of investors and entrepreneurs into deals is a major factor to take into account in both the empirical and theoretical literature on financial contracting.

An intriguing theoretical question that our paper raises is how various contractual features come about in different markets. Our results imply that in a relatively non-competitive and unregulated VC market, any feature with a sufficiently VC-friendly tradeoff between the impact on the firm value and the VC share of it would be implemented via a contract term. The result is a multitude of terms that are either always present or have some variation in the data. At the same time, it is possible that in more competitive markets, or in markets with more experienced firm managers, many of such contractual features are competed away, leading to simpler contracts. It seems important to develop a rich model to study the equilibrium number, complexity, and investor bias of contractual features in various public and private markets with different organization.

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Appendix

A Proof of Proposition 1

The agents' expected present values are

$$V_i(i) = \frac{1}{1+rdt}\left(\lambda_i dt\left(\int_{e\in\mu_i(i)}\max\{\pi_i(i,e,c^*),V_i(i)\}dF(e)+\int_{e\notin\mu_i(i)}V_i(i)dF(e)\right)+(1-\lambda_i dt)V_i(i)\right), \quad (14)$$

$$V_e(e) = \frac{1}{1+rdt}\left(\lambda_e dt\left(\int_{i\in\mu_e(e)}\max\{\pi_e(i,e,c^*),V_e(e)\}dF(i)+\int_{i\notin\mu_e(e)}V_e(e)dF(i)\right)+(1-\lambda_e dt)V_e(e)\right) \quad (15)$$

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.[31]

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.[32]

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

[32] 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.[33] 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.[34] 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.

[33] 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.

[34] 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

$$E(c_k^*) = \frac{\sum_i \sum_e w_i w_e m(i,e) c_k^*(i,e)}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{16}$$

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

$$V(c_k^*) = \frac{\sum_i \sum_e w_i w_e m(i,e)(c_k^*(i,e) - E(c_k^*))^2}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{17}$$

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

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

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 λ_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, τ, for investor i has mean and variance equal to

$$E(\tau|i) = \frac{1}{\lambda_i p_i}; \quad V(\tau|i) = \frac{1}{(\lambda_i p_i)^2}. \tag{19}$$

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 (19),

$$E(\tau) = \frac{\sum_i \sum_e w_i w_e m(i,e) \frac{1}{\lambda_i p_i}}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{20}$$

Because τ is random for any given deal, its variance is, from the law of total variance,

$$V(\tau) = E[V(\tau|i)] + V[E(\tau|i)]. \tag{21}$$

Using (19), the first term of (21) 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 (20), 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 τ and contract term $c_k^*(i,e)$, $k \in \{1..D\}$ across all deals can similarly be derived from the law of total covariance,

$$Cov(\tau, c_k^*) = E[Cov(\tau, c_k^*|i)] + Cov[E(\tau|i), E(c_k^*|i)] \tag{22}$$

The first term of (22) is zero, because the time between deals does not vary with contract terms for a given investor. Using (16), (19), (20), 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 IPO-related moments

Recall that the probability of an IPO for a given deal is

$$Pr(IPO = 1|i,e) = \Phi(\kappa_0 + \kappa_1 \cdot \pi(i,e,c^*(i,e))), \tag{23}$$

with Φ the standard normal c.d.f. The expected IPO rate across all deals is then

$$\begin{aligned} E(IPO) &= E\left[E(IPO = 1|i,e)\right] \\ &= E\left[Pr(IPO = 1|i,e)\right] \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e) \Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e)))}{\sum_i \sum_e w_i w_e m(i,e)}. \end{aligned} \tag{24}$$

Similarly to (21), because IPO is random for any given deal, its variance is, from the law of total variance,

$$\begin{aligned} V(IPO) &= E(V(IPO|i,e)) + V(E(IPO|i,e)) \\ &= E(Pr(IPO = 1|i,e) \cdot (1 - Pr(IPO = 1|i,e))) + V(Pr(IPO = 1|i,e)) \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e) \Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))) \cdot (1 - \Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))))}{\sum_i \sum_e w_i w_e m(i,e)} \\ &\quad + \frac{\sum_i \sum_e w_i w_e m(i,e) (\Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))) - E(IPO))^2}{\sum_i \sum_e w_i w_e m(i,e)}, \end{aligned} \tag{25}$$

where we use (23) and (24) to arrive at the final expression.

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

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

where $E(Cov(IPO, c_k^*|i,e))$ 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 IPO outcome. To arrive at the final expression, we use (16), (23), and (24).

Finally, the covariance between IPO and τ across all deals is

$$\begin{aligned} Cov(\tau, IPO) &= E[Cov(\tau, IPO|i)] + Cov[E(\tau|i), E(IPO|i)] \quad (27) \\ &= Cov[E(\tau|i), E(IPO|i)] \\ &= \sum_i w_i [E(\tau|i) - E(\tau)] \cdot [E(IPO|i) - E(IPO)] \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e) \left(\frac{1}{\lambda_i p_i} - E(\tau)\right) \cdot (\Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e))) - E(IPO))}{\sum_i \sum_e w_i w_e m(i,e)}, \end{aligned}$$

where $E[Cov(\tau, IPO|i)]$ is zero because the time between deals does not vary with the start-up's IPO outcome for a given investor. To arrive at the final expression, we use (19), (20), (23), (24), 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 VCs and entrepreneurs tend to cluster in blocks, however these blocks are imperfect. Block segregation is a standard result in the search-matching literature in the absence of endogenous contracting (e.g., see Shimer and Smith (2000) and Smith (2011)). The following proposition shows that if the contracts were, instead, exogenous, we would also obtain a clear block segregation and, immediately, positively assortative matching (e.g., good VCs would always match with good entrepreneurs):

Proposition 2. *Suppose that $c^*(i,e) \equiv const$ is exogenous. Then, the model solution admits block segregation: for $k \geq 1$, any investor 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 $(\hat{i}_k, \hat{e}_k)$, $k \geq 1$ are endogenous functions of model parameters.*

Proof: The result follows from Shimer and Smith (2000) and Smith (2011), because, when $c^*(i,e) \equiv const$, $\pi(i,e,c^*)$ depends on types i and e multiplicatively.

When contracts are endogenous, there is, in general, no clear block segregation. Moreover, 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. This result calls into question the validity of simply assuming positively assortative matching in settings with contracts (e.g., Cong, 2018). Intuitively, because contracts are chosen endogenously, it pays, for a lower-quality VC who otherwise would have been excluded by the block of best entrepreneurs, to offer a larger fraction of the start-up to such entrepreneurs to make them enter the 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 benefits.[35]

F Robustness and Extensions

F.1 Matching Function

The degree of complementarity between deal parties is typically unknown to the researcher. Therefore a concern can be that the impact of contract terms is estimated incorrectly because the impact of qualities i and e on the firm value is not multiplicative. To address this concern, we modify π to flexibly account for the degree of complementarity. Assume that π is constant-elasticity-of-substitution (CES):

$$\pi(i, e, c^*) = \left(\sum_{j \in \{i,e\}} \frac{1}{2} j^{2\rho} \right)^{\frac{1}{\rho}} \cdot h(c^*). \tag{28}$$

In particular, when $\rho \to 0$, π converges to (4). When $\rho = 1$, qualities of the counterparties are perfect substitutes. Finally, when $\rho \to -\infty$, qualities are perfect complements. We estimate ρ together with other parameters.

Panel A of Table XI shows that the matching function exhibits some complementarity: $\hat{\rho} = -1.71$. This complementarity mainly shifts $\hat{\gamma}_1$, the intercept in the split of value equation: it becomes higher. In the presence of complementarities, all else equal, high-quality VCs become more desirable, wield more bargaining power, and offer more VC-friendly terms in equilibrium. A shift in $\hat{\gamma}_1$ implies that the main model assigns the VC-friendly impact of complementarities to this all-inclusive parameter that is designed to capture the impact of contract terms that are always present. At the same time, other estimates, as well as their impact on the total value and its split, remain relatively unaffected.

F.2 Overconfidence

There is ample evidence that entrepreneurial individuals are overconfident, i.e., assign a higher precision to their information than the data would suggest.[36] Our model is easily extendable to allow for overconfidence on the part of agents. Modify (5) and (6) as

$$\pi_i^j(i, e, c^*) = \alpha(c^*) \cdot \pi^j(i, e, c^*), \tag{29}$$

$$\pi_e^j(i, e, c^*) = (1 - \alpha(c^*)) \cdot \pi^j(i, e, c^*), \tag{30}$$

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

[36]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)

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

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

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 XI shows that even a rather substantial entrepreneurial overconfidence does not appear to 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 its 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 startup'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 startup. In particular, VCs typically cannot have an investment in any startup 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 (10) as

$$h(c^*) = \exp\left\{\beta_0 \log c_0^* + \beta_1 c_1^* + \beta_2 c_1^{*2} + \beta_{3:D+1}'(1 - c_1^*) c_{2:D}^*\right\}, \tag{32}$$

and modify (5) as

$$\pi_i(i, e, c^*) = \phi(c_0^*) \cdot \alpha(c^*) \cdot \pi(i, e, c^*), \tag{33}$$

keeping (6) unchanged. Equation (32) implies that the matching function in the presence of endogenous investment exhibits returns to scale with factor β_0. Equation (33) 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 $\phi(c_0^*) = \exp\{\gamma_0 c_0^*\}$.[37]

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 compar-

[37]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).

ative statics with respect to β_0 and γ_0. For all reasonable parameter values, the model produces several unsatisfactory results. First, investments by the worst VCs are substantially higher than by the best VCs in a block, as they try to retain better entrepreneurs, even though worse VCs in practice have tighter upper bounds on capital invested in a single startup. 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 β_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 correct the model, 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.[38] In turn, it is unlikely that the impact of other contract terms on deal values and their split would be substantially affected.

F.4 Exogenous 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. In reality, there can be other covariates that can cause the change in the set of counterparties an agent is interested in, in turn leading to variation in the contract a given combination of agents signs. One clear example often considered in the VC literature is how "entrepreneur-friendly" the market is, measured for example by the overall amount of VC capital raised (Gompers and Lerner (2000)). In a more friendly market, the same entrepreneur can end up with a better VC at the same contract, or with the same VC but a better contract.

To address this concern, we extend the model to include the possibility of a global state change x (such as the overall amount of VC capital raised by funds), which affects the agents in the market via distributions $F_{i,x}(i)$ and $F_{e,x}(e)$ and frequencies of encounters $\lambda_{i,x}$ and $\lambda_{e,x}$. The empirical proxy for the global state ("light" versus "tight" VC capital constraints) is whether the annual average of the last T years' capital raised by early-stage VC funds is above or below the 2002–2009 annual within-sample median of capital raised. In separate estimations, we use $T = 3$ and $T = 1$. $T = 3$ assumes that tight capital constraints can affect VCs with a lag, as at the time of the shock, their current funds have already raised capital which cannot be retracted, so that these funds' spending is unaffected. At the same time, new funds formed in the future would have to operate under new constraints. $T = 1$ assumes that the impact of tight capital constraints on the VC market is more immediate. [FIGURES OF STATE CHANGES AND RESULTS TO BE ADDED]

F.5 Bargaining Power

Entrepreneurs' endogenously determined expected present value $V_e(e)$ defines the lower bound on their payoff π_e in contract negotiations. In reality, entrepreneurs can have additional bargaining power (e.g., they can raise financing outside of the VC market). The theoretical literature on bargaining when both sides of the process wield bargaining power is extensive, and the results

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

depend crucially on the agents' information sets, discount factors, sequence of moves, and outside options. Without imposing substantial structure on the bargaining process and potentially misspecifying it, we incorporate entrepreneurs' additional bargaining power into the model in reduced form. Specifically, the contract that the VC offers, (7), is modified in the following way:

$$c^*(i,e) = \underset{c \in C : \pi_e(i,e,c) \geq (1+\gamma) V_e(e)}{\arg\max} \pi_i(i,e,c), \tag{34}$$

where $\gamma \geq 0$ represents entrepreneurs' additional bargaining power. We compare parameter estimates of the main model with those of the modified model for $\gamma = 0.05$ and $\gamma = 0.1$.[39] [RESULTS TO BE ADDED]

F.6 Multiple Markets

The VC market is segmented, so that VCs and entrepreneurs are isolated in different geographical locations and industries. In model terms, this leads to potentially submarket-specific distributions of qualities, $F_i(i)$ and $F_e(e)$, an encounter frequencies, λ_i and λ_e. It is also reasonable to think of success outcomes (IPOs and follow-on financings) as different across industries and, possibly, locations, leading to submarket-specific κ_0 and κ_1. We split the sample into several submarkets based on industry (hi-tech, biotech, healthcare,...) and geographical locations (California, Massachusetts, Illinois, Texas,...) and estimate submarket-specific parameters. At the same time, we keep sensitivities of the total value and its split to contract terms the same across submarkets (it is less likely that given everything else the same, agents' incentives would be different). [RESULTS TO BE ADDED]

[39] In additional robustness checks, we formally model the outcome of bargaining as a one-shot Nash Bargaining Solution. It is unlikely that this model of bargaining represents well the actual process. However, our estimates are quantitatively unaffected.

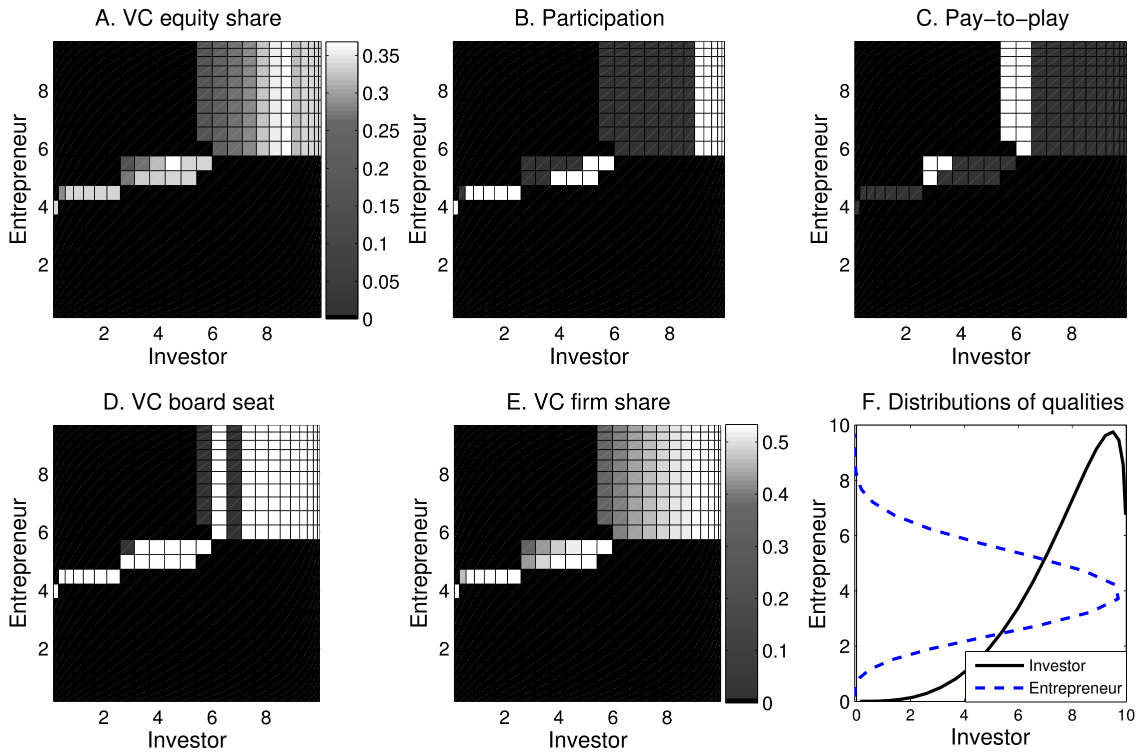

Figure 1: **Equilibrium contract terms for estimated model parameters.** For each combination of VC and entrepreneur quality, Panel A shows the VC equity share, Panel B shows participation preference, Panel C shows pay-to-play, Panel D shows the VC board seat, and Panel E shows the resulting VC share 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 black. The VC equity share and VC share of the firm take values in $[0, 1]$ and are shown in greyscale. In particular, the unconstrained VC-optimal contract, $c^* = (0.334, 1, 0, 1)$, includes 33.4% VC equity and leaves the VC with 53.4% of the firm. Participation preference, pay-to-play and the VC board seat take values in $\{0, 1\}$, and their inclusion is shown in white.

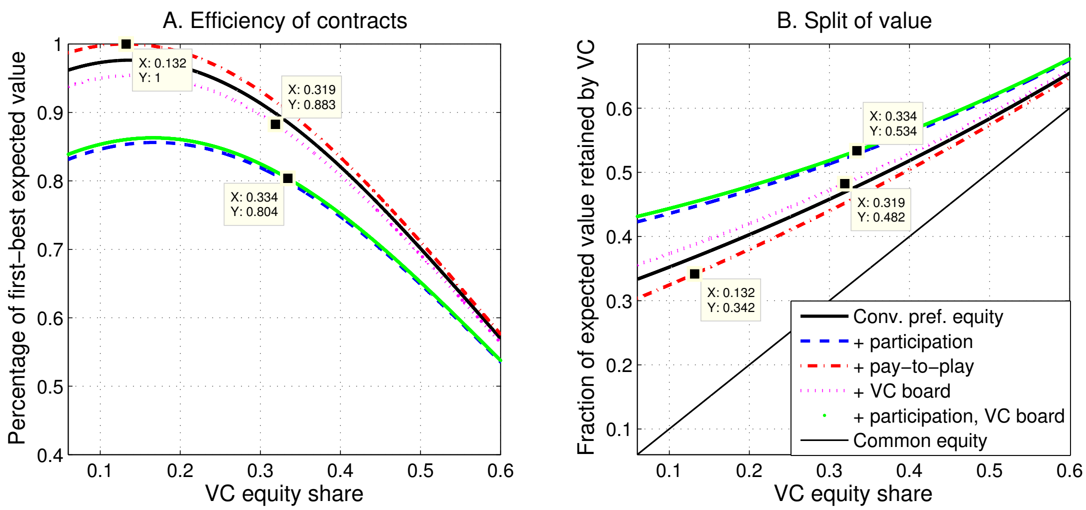

Figure 2: **Impact of contract terms on total value and its split.** For reasonable values of VC equity share, $c_1 \in [0.06, 0.6]$, and for combinations of participation preference, pay-to-play, and the VC board seat that occur in equilibrium, Panel A shows the ratio of the total firm value to the maximal value; Panel B shows the fraction of the total value retained by the VC. Datatips show the impact of the contract that maximizes the value, $c^{Max} = (0.132, 0, 1, 0)$, the average contract, $c^{*,Avg} = (0.319, 0, 0, 1)$, and the unconstrained VC-optimal contract, $c^{*,Unc} = (0.334, 1, 0, 1)$, on the total value and its split. These three contracts achieve 100%, 88.3%, and 80.4% of the maximal value and leave the VC with 34.2%, 48.2%, and 53.4% of the firm.

Table I: Variable definitions.

Notes: The table describes the variables used throughout the paper.

Variable	**Definition**
Firm age at financing (yrs)	Years from the startup's date of incorporation to the date of the first round financing.
Information technology	An indicator equal to one if the startup's industry is information technology.
Healthcare	An indicator equal to one if the startup'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 (2009 $m)	Total capital raised (in millions of 2009 dollars) in the startup's first financing rounds (across all investors).
Post-money valuation (2009 $m)	The post-money valuation of the first round financing (capital raised plus pre-money valuation, in millions of 2009 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 pref.	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 mult. > 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 one 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 startup 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 startup had an IPO by the end of 2017Q2.
Acquired	An indicator variable that is equal to one if the startup was acquired the end of 2017Q2.
IPO or Acq. $> 2X$ capital	An indicator variable that is equal to one if the startup 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 startup had gone out of business by the end of 2017Q2.
Still private	An indicator variable that is equal to one if the startup had not exited by the end of 2017Q2.

Table II: Summary statistics.

Notes: Summary statistics of start-ups and their first round equity financings for the sample financed from 2002 - 2015 detailed in Section 3. For exit outcomes IPO, acquisitons and related, we only consider start-ups financed before 2010.

Panel A: Firm and financing characteristics

	Obs	Mean	25th	Median	75th	Std dev
Firm age at financing (yrs)	10,973	1.83	0.55	1.25	2.51	1.82
Information Tech.	10,973	0.47	0.00	0.00	1.00	0.50
Healthcare	10,973	0.19	0.00	0.00	0.00	0.40
Years since last round (VC)	9,228	0.79	0.10	0.30	0.86	1.32
Syndicate size	10,973	2.37	1.00	2.00	3.00	1.53
Capital raised in round (m, real)	9,964	5.22	1.17	2.73	6.16	7.91
Post-money valuation (m)	5,988	18.29	5.95	10.73	19.34	34.82
Financing year	10,973	2009.62	2006.00	2010.00	2013.00	3.91

Panel B: Contracts

	Obs	Mean	25th	Median	75th	Std dev
% equity sold to investors	6,040	0.35	0.22	0.32	0.46	0.18
	count	mean	p25	p50	p75	sd
Participating pref.	4,794	0.41				
Common stock sold?	5,009	0.05				
Liquidation mult. > 1	4,790	0.03				
Cumulative dividends	4,590	0.20				
Full ratchet	3,463	0.01				
Pay to play	2,955	0.10				
Redemption	3,383	0.35				
VC has board seat	10,973	0.62				

Panel C: Exit outcomes

	Obs	Mean	25th	Median	75th	Std dev
IPO	4,993	0.04				
Acquired	4,993	0.39				
IPO or Acq. $> 2X$ capital	4,993	0.16				
Out of business	4,993	0.17				
Still private	4,993	0.38				

Table III: Summary statistics: with and without contracts data.

Notes: Summary statistics of start-ups and their first round equity financings for the sample financed from 2002 - 2015 detailed in Section 3. The panel "Deals with contract data" report the summary statistics for financings that have all the major contract terms available in the data. The second panel "All deals" include all financings regardless of data missingness.

	Deals with contract data				All deals			
	Obs	Mean	Median	Std dev	Obs	Mean	Median	Std dev
Firm age at financing (yrs)	2,184	1.65	1.14	1.69	10,973	1.83	1.25	1.82
Information Tech.	2,184	0.47	0.00	0.50	10,973	0.47	0.00	0.50
Healthcare	2,184	0.25	0.00	0.43	10,973	0.19	0.00	0.40
Years since last round (VC)	2,184	0.69	0.25	1.21	9,228	0.79	0.30	1.32
Syndicate size	2,184	2.56	2.00	1.46	10,973	2.37	2.00	1.53
Capital raised in round (m, real)	2,184	7.15	4.91	8.81	10,973	5.22	3.16	7.54
Financing year	2,184	2008.28	2008.00	3.57	10,973	2009.62	2010.00	3.91
Out of business	1,348	0.12	0.00	0.33	4,993	0.17	0.00	0.37
Still private	1,348	0.38	0.00	0.48	4,993	0.38	0.00	0.49
IPO	1,348	0.10	0.00	0.30	4,993	0.04	0.00	0.21
IPO or Acq. $> 2X$ capital	1,348	0.23	0.00	0.42	4,993	0.16	0.00	0.37

Table IV: Pairwise correlations and covariances.

Notes: The table reports the correlations (upper right triangle of matrix) and covariances (lower triangle of the matrix) for the contract, deal flow and outcome variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
% equity sold to investors, (1)	1	.011	.283	.096	.268	.05	.208	.029	.195	.16
Liquidation multiple > 1?, (2)	0	1	.047	.072	.042	.002	-.007	.033	.014	.011
Pay-to-play, (3)	.016	.003	1	.091	.161	-.039	.073	.019	.151	.085
Cumulative dividends, (4)	.007	.005	.011	1	.23	.063	.039	.102	.024	.007
Participation preference, (5)	.022	.004	.024	.045	1	.065	.087	.097	.044	.043
Full ratchet, (6)	.001	0	-.001	.003	.003	1	.01	-.006	-.022	.005
Board seat, (7)	.015	0	.008	.005	.015	0	1	-.008	.102	.127
Time between rounds, (8)	.006	.007	.007	.049	.059	-.001	-.005	1	-.007	-.023
IPO, (9)	.007	.001	.011	.002	.004	0	.008	.008	1	.469
IPO/Acquisition, (10)	.01	.001	.01	.001	.007	0	.019	-.01	.022	1

Table V: Post-money valuations, IPOs and contract terms

Notes: The table reports OLS regressions for the log of post-money valuation (columns (1)-(4)) and IPO indicator variable (columns (5)-(8)). The sample includes all startups where we can observe the full assortment of contract terms financed between 2002 and 2012 for the former and 2002–2009 for the last four columns. "% equity sold" is the total (as-if-common) equity stake sold in the startup'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 (2009 dollars). "Year FE" are fixed effects for the financing year. "Year founded FE" are fixed effect for the startup's founding year. "State FE" are fixed effects for the startup's state and "Industry FE" are fixed effects for industry. Standard errors reported in parentheses, clustered at the VC firm. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	Log post-money				IPO			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% equity sold	-3.467***	-2.586***	-4.089***	-4.357***	-0.358*	-0.379**	-0.397*	-0.422*
	(0.369)	(0.381)	(0.438)	(0.402)	(0.175)	(0.143)	(0.188)	(0.194)
% equity sold^2	4.002***	2.965***	4.467***	4.716***	0.610**	0.590**	0.645*	0.684*
	(0.352)	(0.373)	(0.437)	(0.408)	(0.244)	(0.199)	(0.296)	(0.296)
Participating pref.	-0.0438			-0.0552	-0.0426**			-0.0476**
	(0.0318)			(0.0465)	(0.0124)			(0.0142)
VC has board seat		0.348***		0.320***		0.0390***		0.0504*
		(0.0319)		(0.0730)		(0.0104)		(0.0209)
Pay-to-play			0.287***	0.277***			0.0368	0.0387
			(0.0807)	(0.0806)			(0.0366)	(0.0366)
Constant	2.733***	3.090***	2.372***	2.452***	0.00737	-0.0587	0.0111	-0.0850
	(0.294)	(0.302)	(0.291)	(0.476)	(0.0738)	(0.0488)	(0.0964)	(0.0752)
Observations	4232	5977	2417	2412	1887	2629	1342	1340
Adj. R^2	0.113	0.128	0.121	0.132	0.0361	0.0375	0.0328	0.0398
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Year founded FE	Y	Y	Y	Y	Y	Y	Y	Y
State FE	Y	Y	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y	Y	Y

Table VI: Empirical and theoretical moments.

Notes: The table describes empirical moments and their theoretical counterparts computed at estimated model parameters. Panel A (Panel B) describes moments of the model where success outcomes are captured by IPO (follow-on financing).

	A. IPO		**B. Follow-on financing**	
Moment	Empirical	Theoretical	Empirical	Theoretical
Avg. time since last VC financing	0.6611	0.7253	0.6802	0.7321
Var. time since last VC financing	1.1329	0.7502	1.4259	0.5573
Avg. share of VC equity	0.4047	0.3651	0.3749	0.3185
Var. share of VC equity	0.0312	0.0021	0.0314	0.0018
Cov. time since last VC financing and share of VC equity	0.0010	0.0043	0.0055	0.0002
Avg. participation	0.5858	0.5271	0.4564	0.4505
Cov. time since last VC financing and participation	0.0494	0.0566	0.0503	-0.0081
Cov. share of VC equity and participation	0.0127	0.0110	0.0198	0.0056
Avg. pay-to-play	0.1418	0.1321	0.1067	0.0877
Cov. time since last VC financing and pay-to-play	-0.0037	-0.0247	0.0071	-0.0038
Cov. share of VC equity and pay-to-play	0.0112	-0.0122	0.0143	-0.0092
Cov. participation and pay-to-play	0.0102	-0.0696	0.0215	-0.0395
Avg. VC board seat	0.8970	0.9955	0.8799	0.9080
Cov. time since last VC financing and VC board seat	-0.0225	0.0008	-0.0171	0.0003
Cov. share of VC equity and VC board seat	0.0062	0.0009	0.0080	0.0072
Cov. participation and VC board seat	-0.0009	0.0024	0.0063	0.0414
Cov. pay-to-play and VC board seat	0.0034	-0.0039	0.0059	-0.0165
Avg. success rate	0.1007	0.0571	0.7423	0.7948
Cov. time since last VC financing and success rate	-0.0122	0.0145	-0.0095	0.0263
Cov. share of VC equity and success rate	0.0068	0.0004	-0.0060	0.0008
Cov. participation and success rate	-0.0090	0.0031	-0.0112	-0.0129
Cov. pay-to-play and success rate	0.0096	-0.0027	-0.0044	-0.0101
Cov. VC board seat and success rate	0.0052	0.0000	0.0078	0.0004

Table VII: Parameter estimates.

Notes: The table describes parameter estimates of the model. Panel A (Panel B) describes estimates of the model where success outcomes are captured by IPO (follow-on financing). Significance: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

	A. IPO		**B. Follow-on financing**	
Parameter	Estimate	Standard error	Estimate	Standard error
Distribution of qualities, a_i	2.4691	2.2702	4.0736***	0.6468
Distribution of qualities, b_i	1.1082	2.6627	1.1711**	0.5522
Distribution of qualities, a_e	6.6532**	3.0602	5.4974***	1.8029
Distribution of qualities, b_e	9.0887	8.2168	7.9767***	1.5601
Frequency of encounters, λ_i	9.0716***	1.9202	8.8588***	0.0424
Frequency of encounters, λ_e	7.2996**	3.9200	7.9642***	1.3371
Probability of success, intercept, κ_0	-3.0329*	1.7502	-2.7193	1.8791
Probability of success, total value, κ_1	0.0379	0.0392	0.0912*	0.0468
Total value, share of VC equity, β_1	0.7942*	0.4770	0.6907**	0.2802
Total value, share of VC equity squared, β_2	-2.5179***	0.5116	-2.5154***	0.7203
Total value, participation, β_3	-0.1527***	0.0182	-0.1551***	0.0031
Total value, pay-to-play, β_4	0.0269	0.0385	0.0277	0.2188
Total value, VC board seat, β_5	-0.0198	0.0144	-0.0266	0.0465
Total value, participation $\times$ pay-to-play, β_6	0.0124	0.0996	0.0125	0.3940
Total value, participation $\times$ VC board seat, β_7	0.0351*	0.0182	0.0360***	0.0031
Total value, pay-to-play $\times$ VC board seat, β_8	0.0128	0.0137	0.0126	0.3478
Split of value, intercept, γ_1	-0.2673	0.1872	-0.3655***	0.0764
Split of value, participation, γ_2	-0.1625***	0.0067	-0.1534***	0.0014
Split of value, pay-to-play, γ_3	0.0464	0.0388	0.0468***	0.0086
Split of value, VC board seat, γ_4	-0.0354***	0.0105	-0.0366**	0.0181
Split of value, participation $\times$ pay-to-play, γ_5	0.0104	0.2041	0.0087	0.3556
Split of value, participation $\times$ VC board seat, γ_6	0.0216***	0.0067	0.0212***	0.0014
Split of value, pay-to-play $\times$ VC board seat, γ_7	0.0097	0.0847	0.0101	0.1446

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

Notes: 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	49.99	50.01
0-25% quantile	68.65	45.17	54.83
25-50% quantile	105.64	48.55	51.45
50-75% quantile	113.93	51.80	48.20
75-100% quantile	121.26	53.36	46.64
Entrepreneur			
All deals	100	49.99	50.01
0-25% quantile	0	–	–
25-50% quantile	4.13	53.36	46.64
50-75% quantile	38.86	52.58	47.42
75-100% quantile	104.91	49.91	50.09

Panel B: Deal frequencies

Frequency of deals	$\Lambda^*(Sub)$
Investor	
All deals	1.366
0-25% quantile	1.593
25-50% quantile	1.288
50-75% quantile	1.288
75-100% quantile	1.288
Entrepreneur	
All deals	1.228
0-25% quantile	0
25-50% quantile	0.001
50-75% quantile	0.332
75-100% quantile	4.612

Panel C: Present values of deals

Ratio of PV of deals	$\frac{PV^*(Sub)}{PV^*(All)}$
Investor	
All deals	76.94
0-25% quantile	12.61
25-50% quantile	21.58
50-75% quantile	17.89
75-100% quantile	24.87
Entrepreneur	
All deals	23.06
0-25% quantile	0
25-50% quantile	0.09
50-75% quantile	4.82
75-100% quantile	18.15

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

Notes: The 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 of the table 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 of the table 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 of the table reports the change in present values of all deals in the market, $\Delta PV^{cf}(All) = PV^{cf}(All) - PV^{*}(All)$, as percentages of the estimated present value of deals in the market, $PV^{*}(All)$. Table A1 in the appendix provides the detailed analysis of quartiles of VC and entrepreneur qualities.

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	-0.11	-0.11	0
Equilibrium	1.82	-0.95	2.77
No pay-to-play			
Rebalanced terms only	-0.13	-0.13	0
Equilibrium	0.32	0.29	0.02
No VC board seats			
Rebalanced terms only	-0.46	-0.46	0
Equilibrium	2.18	-1.22	3.40

Panel B: Deal frequencies

Ratio of deal frequencies	$\frac{\Delta\Lambda^{cf}(All)}{\Lambda^{*}(All)}$
No participation preference	2.27
No pay-to-play	-1.46
No VC board seat	2.27

Panel C: Present values of deals

Ratio of present values	$\frac{\Delta PV^{cf}(All)}{PV^{*}(All)}$
No participation preference	3.43
No pay-to-play	-0.08
No VC board seat	3.34

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

Notes: The table examines effects of three counterfactuals, in which VCs and entrepreneurs encounter each other with 2X, 5X, and 10X frequency compared to the estimated frequency. It reports the change in present values of all deals in the market, $\Delta PV^{cf}(All) = PV^{cf}(All) - PV^{*}(All)$, 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	$\frac{\Delta PV^{cf}(All)}{PV^{*}(All)}$
2X frequencies of encounters	-1.99
5X frequencies of encounters	1.35
10X frequencies of encounters	3.90

Table XI: Parameter estimates for model extensions.

Notes: The table describes parameter estimates of model extensions described in Section 6. Panel A describes the estimates of the model with CES matching function. Panel B describes estimates of the model with entrepreneurial overconfidence. Significance: Significance: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

	A. CES		**B. E overconfidence**	
Parameter	Estimate	Standard error	Estimate	Standard error
Distribution of qualities, a_i	3.1925***	0.7194	3.6183	
Distribution of qualities, b_i	1.6449***	0.1516	1.2567	
Distribution of qualities, a_e	6.9393***	0.2307	5.5027	
Distribution of qualities, b_e	9.2099***	2.2944	7.6557	
Frequency of encounters, λ_i	7.4274***	0.1107	8.2074	
Frequency of encounters, λ_e	8.9847***	0.8950	7.0369	
Probability of IPO, intercept, κ_0	-2.7607	2.3050	-2.6933	
Probability of IPO, total value, κ_1	0.0170	0.0599	0.0150	
Total value, share of VC equity, β_1	0.4009***	0.0318	0.3700	
Total value, share of VC equity squared, β_2	-2.4746***	0.0818	-2.4301	
Total value, participation preference, β_3	-0.1621***	0.0203	-0.1573	
Total value, pay-to-play, β_4	0.0360	0.2335	0.0311	
Total value, VC board seat, β_5	-0.0504	0.0457	-0.0500	
Total value, part. pref. × pay-to-play, β_6	0.0062	0.2274	0.0125	
Total value, part. pref. × VC board seat, β_7	0.0193	0.1829	0.0201	
Total value, pay-to-play × VC board seat, β_8	0.0089	0.0934	0.0121	
Split of value, intercept, γ_1	-0.1646**	0.0797	-0.2628	
Split of value, participation preference, γ_2	-0.1607***	0.0076	-0.1585	
Split of value, pay-to-play, γ_3	0.0521	0.4716	0.0389	
Split of value, VC board seat, γ_3	-0.0532	0.0384	-0.0516	
Split of value, part. pref. × pay-to-play, γ_5	0.0084	0.0089	0.0095	
Split of value, part. pref. × VC board seat, γ_6	0.0227	0.1948	0.0217	
Split of value, pay-to-play × VC board seat, γ_7	0.0103	0.0435	0.0105	
Substitutability of qualities, ρ	-1.7125	1.0025	–	–
Entrepreneur overconfidence (fixed)	–	–	25%	–

Table A1: Start-up values, deal frequencies, and present values of deals in the VC market in the presence of contract features regulation: a detailed analysis.

Notes: The 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 of the table reports the change in the expected firm value and its split across all deals and deals completed by quartiles of investor and entrepreneur qualities. *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 expected firm value across all deals and in quartile subsamples, $\Delta\pi^{cf}(All) = \pi^{cf}(All) - \pi^*(All)$ and $\Delta\pi^{cf}(Sub) = \pi^{cf}(Sub) - \pi^*(Sub)$, and the change in expected values of investors and entrepreneurs across all deals and in quartile subsamples, $\Delta\pi_j^{cf}(All) = \pi_j^{cf}(All) - \pi_j^*(All)$ and $\Delta\pi_j^{cf}(Sub) = \pi_j^{cf}(Sub) - \pi_j^*(Sub)$, $j \in \{i, e\}$, are percentages of estimated expected firm value in the relevant subsample, $\pi^*(All)$ and $\pi^*(Sub)$ correspondingly. Panel B of the table reports the change in expected deal frequencies in the entire market, $\Delta\Lambda_j^{cf}(All) = \Lambda_j^{cf}(All) - \Lambda_j^*(All)$, and by quartiles of investor and entrepreneur qualities, $\Delta\Lambda_j^{cf}(Sub) = \Lambda_j^{cf}(Sub) - \Lambda_j^*(Sub)$, $j \in \{i, e\}$, as percentages of the estimated deal frequency in the relevant subsample, $\Lambda_j^*(All)$ and $\Lambda_j^*(Sub)$. Panel C of the table reports the change in present values of all deals in the entire market, $\Delta PV^{cf}(All) = PV^{cf}(All) - PV^*(All)$, and deals completed by quartiles of investor and entrepreneur qualities, $\Delta PV_j^{cf}(Sub) = PV_j^{cf}(Sub) - PV_j^*(Sub)$, $j \in \{i, e\}$, as percentages of the estimated present value of deals in the relevant subsample, $PV^*(All)$ and $PV_j^*(Sub)$ correspondingly.

Panel A: Start-up values

Subsample (Sub)	All deals (All)			0-25% j quantile			25-50% j quantile			50-75% j quantile			75-100% j quantile		
Ratio of expected profits	$\frac{\Delta\pi^{cf}(All)}{\pi^*(All)}$	$\frac{\Delta\pi_i^{cf}(All)}{\pi^*(All)}$	$\frac{\Delta\pi_e^{cf}(All)}{\pi^*(All)}$	$\frac{\Delta\pi^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi_i^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi_e^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi_i^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi_e^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi_i^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi_e^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi_i^{cf}(Sub)}{\pi^*(Sub)}$	$\frac{\Delta\pi_e^{cf}(Sub)}{\pi^*(Sub)}$
No participation preference															
j =investor															
Rebalanced terms only	-0.11	-0.11	0	-0.07	-0.07	0	0	0	0	-0.07	-0.07	0	-0.28	-0.28	0
Equilibrium	1.82	-0.95	2.77	-2.92	-1.28	-1.64	3.86	-0.75	4.61	3.69	-0.09	3.78	4.49	-0.08	4.57
j =entrepreneur															
Rebalanced terms only	-0.11	-0.11	0	–	–	–	-0.28	-0.28	0	-0.24	-0.24	0	-0.11	-0.11	0
Equilibrium	1.82	-0.95	2.77	–	–	–	56.52	26.44	30.07	16.49	5.47	11.02	3.89	0.04	3.86
No pay-to-play															
j =investor															
Rebalanced terms only	-0.13	-0.13	0	-0.63	-0.63	0	0	0	0	0	0	0	0	0	0
Equilibrium	0.32	0.29	0.02	-0.75	0.06	-0.81	0	0	0	0	0	0	0	0	0
j =entrepreneur															
Rebalanced terms only	-0.13	-0.13	0	–	–	–	0	0	0	-0.02	-0.02	0	-0.13	-0.13	0
Equilibrium	0.32	0.29	0.02	–	–	–	0	0	0	-0.03	0	-0.03	0.40	0.34	0.06
No VC board seat															
j =investor															
Rebalanced terms only	-0.46	-0.46	0	-0.23	-0.23	0	-0.18	-0.18	0	-0.55	-0.55	0	-0.81	-0.81	0
Equilibrium	2.18	-1.22	3.40	-2.59	-1.58	-1.00	4.32	-0.96	5.28	4.03	-0.37	4.40	4.81	-0.38	5.19
j =entrepreneur															
Rebalanced terms only	-0.46	-0.46	0	–	–	–	-0.81	-0.81	0	-0.74	-0.74	0	-0.45	-0.45	0
Equilibrium	2.18	-1.22	3.40	–	–	–	56.99	26.00	30.99	16.87	5.15	11.72	4.26	-0.24	4.50

Panel B: Deal frequencies

Subsample (Sub)	All deals (All)	0-25% j quantile	25-50% j quantile	50-75% j quantile	75-100% j quantile
Ratio of deal frequencies	$\frac{\Delta\Lambda_j^{cf}(All)}{\Lambda_j^*(All)}$	$\frac{\Delta\Lambda_j^{cf}(Sub)}{\Lambda_j^*(Sub)}$	$\frac{\Delta\Lambda_j^{cf}(Sub)}{\Lambda_j^*(Sub)}$	$\frac{\Delta\Lambda_j^{cf}(Sub)}{\Lambda_j^*(Sub)}$	$\frac{\Delta\Lambda_j^{cf}(Sub)}{\Lambda_j^*(Sub)}$
No participation preference					
j =investor	2.27	7.61	0	0	0
j =entrepreneur	2.27	–	388.69	54.66	-1.94
No pay-to-play					
j =investor	-1.46	-4.90	0	0	0
j =entrepreneur	-1.46	–	0	0	-1.58
No VC board seat					
j =investor	-2.27	7.61	0	0	0
j =entrepreneur	2.27	–	388.69	54.66	-1.94

Panel C: Present values of deals

Subsample (Sub)	Total PV (All)	All deals (All)	0-25% j quantile	25-50% j quantile	50-75% j quantile	75-100% j quantile
Ratio of present values	$\frac{\Delta PV^{cf}(All)}{PV^*(All)}$	$\frac{\Delta PV_j^{cf}(All)}{PV_j^*(All)}$	$\frac{\Delta PV_j^{cf}(Sub)}{PV_j^*(Sub)}$	$\frac{\Delta PV_j^{cf}(Sub)}{PV_j^*(Sub)}$	$\frac{\Delta PV_j^{cf}(Sub)}{PV_j^*(Sub)}$	$\frac{\Delta PV_j^{cf}(Sub)}{PV_j^*(Sub)}$
No participation preference						
j =investor	3.43	-0.90	-0.50	-0.33	-0.03	-0.04
j =entrepreneur	3.43	4.33	0.01	0.02	2.02	2.28
No pay-to-play						
j =investor	-0.08	-0.09	-0.09	0	0	0
j =entrepreneur	-0.08	0.01	0.01	0.01	-0.01	0
No VC board seat						
j =investor	3.34	-1.31	-0.58	-0.43	-0.13	-0.18
j =entrepreneur	3.34	4.65	0.01	0.02	2.10	2.53

Table A2: Start-up values, deal frequencies, and present values of deals in the VC market when search frictions are low: a detailed analysis.

Notes: The table examines effects of three counterfactuals, in which VCs and entrepreneurs encounter each other with 2X, 5X, and 10X 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 deals completed by quartiles of investor and entrepreneur qualities, $\Delta PV_j^{cf}(Sub) = PV_j^{cf}(Sub) - PV_j^{*}(Sub)$, $j \in \{i, e\}$, as percentages of the estimated present value of deals in the relevant subsample, $PV^{*}(All)$ and $PV_j^{*}(Sub)$ correspondingly.

Subsample (Sub)	Total PV (All)	All deals (All)	0-25% j quantile	25-50% j quantile	50-75% j quantile	75-100% j quantile
Ratio of present values	$\frac{\Delta PV^{cf}(All)}{PV^{*}(All)}$	$\frac{\Delta PV_j^{cf}(All)}{PV_j^{*}(All)}$	$\frac{\Delta PV_j^{cf}(Sub)}{PV_j^{*}(Sub)}$	$\frac{\Delta PV_j^{cf}(Sub)}{PV_j^{*}(Sub)}$	$\frac{\Delta PV_j^{cf}(Sub)}{PV_j^{*}(Sub)}$	$\frac{\Delta PV_j^{cf}(Sub)}{PV_j^{*}(Sub)}$
2X Frequencies of encounters						
j =investor	-1.99	5.02	0.81	1.29	1.22	1.70
j =entrepreneur	-1.99	-7.00	0.05	0.06	-4.05	-3.05
5X Frequencies of encounters						
j =investor	1.35	10.07	1.58	2.44	2.48	3.57
j =entrepreneur	1.35	-8.71	0.17	0.21	-4.42	-4.67
10X Frequencies of encounters						
j =investor	3.90	13.90	2.28	3.60	3.29	4.74
j =entrepreneur	3.90	-9.99	0.37	0.47	-4.11	-6.73