Venture Capital Contracts *

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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. 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.

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A large body of academic work examines the problem of financial contracting, and frequently uses the context of an entrepreneur negotiating a financing deal with an investor. Start-up firms are key drivers of innovation and employment growth, and the efficient allocation of capital to early-stage firms is crucial to their success (Solow, 1957). Financial contracting plays a key role at this stage, as information asymmetries and agency problems are severe (Hall and Lerner, 2010). The theoretical literature explains the observed complex contracts between entrepreneurs and venture capitalists (VCs) by the improved incentives and information sharing that they engender, typically assuming that investors are competitive and thus lack self-interest (Cornelli and Yosha, 2003; Kaplan and Strömberg, 2003; Schmidt, 2003; Repullo and Suarez, 2004; Hellmann, 2006).

A contrasting view is that investors negotiate for certain complex 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 VCs have unique talents, are repeat players in the market, and as a result 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-

[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.

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 investor and 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 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 that the entrepreneur is worse off under these terms. They 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, while Kaplan and Strömberg (2004) study investment analyses of 11 VC firms and associate VC board control with VC interference. These findings are 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 model the role of selection, matching, and the importance of VC and entrepreneur quality. 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.

Entrepreneur type (e)	Investor type (i): 1	2	3
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 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

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

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

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

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.[4]

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.

[4]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.

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.[5] 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[6], 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.[7] 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 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.

[5]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.

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

[7]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.

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.[8]

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

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

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

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

[8] 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.

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.[9] 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 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

[9]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.

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.[10]

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.[11] 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 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.

[10]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.

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

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.[12] 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 interested 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). 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

[12] 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.

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.[13] 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 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

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

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 outcomes on contract terms. All estimations consider our main outcome variable IPO, regressed on four major contract terms. Regressions outside of columns 1–3 include fixed effects for financing year, startup founding year, industry and startup headquarters state. The results show that higher share of investor equity, pay-to-play and VC board seat (participation preference) correlate with a higher (lower) IPO success rate. Note that controlling for capital raised (column 7), higher share of investor equity implies lower post-money valuations, which contrasts with its regression coefficient estimate. This contrast may be indicative of either the failure of post-money valuations to capture the true start-up value or the presence of selection biasing the regression output.

In sum, simple regression results reveal predictive power for contract terms, however, they do not merit a causal interpretation due to a host of endogeneity concerns (e.g., endogenous selection among counterparties). In the next section, we estimate the impact of contracts on a start-up using our search and matching model.

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.[14] The Beta distribution is very flexible and can generate hump-shaped, skewed, and even U-shaped distributions. See Appendix B for more detail on the contraction mapping.

We choose flexible functional forms for the impact of contract terms on firm value and its split,

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

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

where $D = \dim\{C\}$ is dimensionality of the contract space. In principle, contact terms entering the functional forms can be generic. However, we pay special attention to the fraction of equity retained by the investor, c_1^*[15], 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

[14] 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.

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

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 easily recovered from post-money valuations, as explained in Section 3.1.[16] 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,

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

$\theta = (\lambda_i, \lambda_e, a_i, b_i, a_e, b_e, \beta, \gamma, \kappa)$. 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 C 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.[17] 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.[18] The model is just identified.

4.2.2 Estimates

Table VI compares theoretical moments computed at estimated parameter values to empirical moments. The model matches well more informative first moments of contract terms, probability of an IPO, and time since last first-round financing, but generally underestimates second moments of these outcomes. While the test of overidentifying restrictions is not possible in a just identified model, the overall fit appears, visually, to be sensible.

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.[19] First,

[17]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.

[18]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.

[19]While parameters related to the VC equity, participation preference, and the intercept in the split of value

coefficients that capture the concave impact of VC equity share on the total value imply that there is an internal VC equity share, at which the first-best total value of a start-up is realized. Specifically, for any combination of participation preference c_2^*, pay-to-play c_3^*, and VC board seat c_4^*, which take values of zero and one, and their interactions $c_{5:7}^*$, an internal VC equity share that maximizes $\pi(i, e, c)$ has to maximize quadratic equation $\hat{\beta}_1 c_1 + \hat{\beta}_2 c_1^2 + \hat{\beta}'_{3:8}(1 - c_1)c_{2:7}^*$. The first-best VC equity share is the one that maximizes the total value across all combinations of other terms. The contract, at which the first-best value of a start-up is achieved[20], is thus $c^{FB} = (0.070, 0, 1, 0)$: 7.0% of VC equity, no participation preference, inclusion of pay-to-play, and no VC board seat.

How far away are equilibrium contracts from the first-best contract? Figure 1 shows contracts for each combination of VC and entrepreneur produced by the model at estimated parameter values. VCs and entrepreneurs tend to cluster in *blocks* (e.g., good VCs usually match with good entrepreneurs), however these blocks are imperfect. 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 D. The average VC equity share across all possible deals is 31.1%. The entire representative contract, in which each term is equal to the average of the term across all possible deals is $c^{*,Avg} = (0.311, 0, 0, 1)$. The worst VCs within a block offer contracts which include either no additional terms or pay-to-play only, which Table VII suggests is beneficial for entrepreneurs and the total value. As the VC quality within a block increases, they offer contracts that first include the VC board seat, then substitute the VC board seat with participation preference, and, finally, include both participation preference and the VC board seat. Table VII suggests that both these terms are detrimental to the total value but beneficial for VCs,

equation are highly significant, parameters related to other contract terms and interactions between terms are not. The GMM objective function is very sensitive to all parameters; however, for parameter values close to zero, each pair of parameters measuring the impact of a term on the total value and its split affects the objective function very similarly, resulting in multicollinearity. The standard approach in linear statistical models is to drop one of the two parameters in each pair (i.e., set it equal to zero) to restore significance of the remaining parameter. However, first, theory suggests that both the total value and its split can potentially be affected by contract terms, and hence these parameters must come in pairs (it would not be intuitive to keep both significant parameters for the participation preference term but drop parameters for other terms). Second, in nonlinear statistical models, to which our model belongs, setting one of the parameters equal to zero versus some other value would affect all other estimates, so one has to come up with a good economic reasoning for a particular value choice. It is arguably easy to write a theoretical model of a self-interested non-competitive VC who uses the VC board seat control term to increase its share of the firm, while the pay-to-play term is used to decrease its share; it is much more difficult to write a model which produces the opposite predictions. Then, if one fixes the VC board seat (pay-to-play) parameter in the split of value equation at any reasonable negative (positive) number (in our case, the coefficients are -0.052 and 0.048), one would estimate a very significant negative (positive) impact of the VC board seat (pay-to-play) on the total value with standard errors changing from 0.098 to 0.003 (from 0.070 to 0.0004). In sum, we believe that given rather large magnitudes of all parameters, all contract terms in our model are economically meaningful.

[20]Note that because we cannot evaluate the impact of terms that are always present, the first-best value is conditional on the presence of these terms.

with a stronger effect for participation preference. Only the best VCs within a block enjoy enough bargaining power to offer contracts with these terms without the risk of driving entrepreneurs away. For the same reason, such VCs also retain a higher-than-average VC equity share, 32.5%, which is an unconstrained maximizer of $\pi_i(i, e, c)$. The entire unconstrained contract that such VCs offer is $c^{*,Unc} = (0.325, 1, 0, 1)$. The distance between equilibrium contracts and c^{FB} thus appears to be large.

To quantify the difference between the equilibrium and first-best total value for each combination of VC and entrepreneur, in the left panel of Figure 2, we change the VC equity share, participation preference, pay-to-play and the VC board seat and show the ratio of the equilibrium to first-best total value for various combinations of terms that occur in equilibrium. For example, a deal with the average contract $c^{*,Avg}$ achieves 82.1% of the first-best total value. A deal signed by the best VCs within a block with the unconstrained contract $c^{*,Unc}$ performs worse and achieves only 73.7% of the first-best 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 literature on contracts in the investor-entrepreneur setting are likely at work in practice. First, in the VC setting, both counterparties' 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^{FB} aligns with this prediction. Second, convertible securities or a combination of debt and equity have been shown to mitigate inefficiencies related to asset substitution (Green, 1984), exit decisions (Hellmann, 2006), sequential investment (Schmidt, 2003), and window dressing (Cornelli and Yosha, 2003). With the exception of Hellmann (2006), the literature does not distinguish between types of convertible securities (e.g., with or without participation preference). In addition, 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 preference, the contract is likely less efficient at dealing with the above inefficiencies than regular convertible equity.[21] However, this term can still be offered in market equilibrium if it increases the value of VCs with substantial bargaining power, even if it is at the expense of the total firm value. At the same time, in the presence of pay-to-play, which affects future investment rounds, the contract is likely more efficient at dealing with the inefficiencies related to sequential investment. Third, control terms in entrepreneurial contracts have been shown to have both benefits of VC support

[21] For example, convex incentives provided by participation preference may force entrepreneurs to gamble for success (e.g., DeMarzo, Livdan, and Tchistyi, 2013, and Makarov and Plantin, 2015) instead of working harder to achieve an IPO. Gambling can increase the likelihood of an IPO by increasing the likelihood of high firm value realizations, yet decrease the firm's expected value.

and costs of VC interference in the presence of costly monitoring (Cestone, 2014).[22] Our results suggest that our only control term, the VC board seat, carries more costs than benefits for the total firm value. However, VCs with substantial bargaining power may still find this term profitable in equilibrium. Our results also align with Kaplan and Strömberg (2004) who use data to associate VC interference with VC board control and VC support with VC equity ownership.[23] 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 either cash flow terms only or the VC board seat only, or a combination of participation preference and the VC board seat. Across all deals, we find positive correlation between participation preference and the VC board seat. 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.[24]

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 preference, pay-to-play, and the VC board seat and show fraction of the total value retained by VCs for various combinations of terms that occur in equilibrium. Even in the absence of participation preference and the VC board seat, 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 multiple) or unavailable in our data are, on average, VC-friendly, as captured by $\gamma_1 = -0.260$. In particular, while 7.0% of VC equity in the first-best contract c^{FB} may appear low, this contract, in fact, leaves the VC with 23.9% of the total value. The presence of participation preference 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 44.6% of the total value. A deal signed by the best VCs within a block with the unconstrained contract $c^{*,Unc}$ leaves the VC with 50.3% of the total value.

The substantial difference between the VC equity share and the fraction of the start-up it

[22]Burkart, Gromb, and Panunzi (1997) also show that investor overmonitoring in publicly traded companies can kill managerial incentive, reducing the firm value. They suggest selling the firm to disperse shareholders, a solution not feasible in the VC setting.

[23]Recently, practitioners have also become concerned with the potentially negative impact of VCs on a board on 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.

[24]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 our model suggests that persistence can at least partly be explained by a market equilibrium, where VCs have substantial bargaining power.

retains due to the inclusion of other contract terms suggests that the post-money valuation, calculated under the assumption that the VC equity share is the only relevant term, is a poor metric to evaluate the start-up value. A sensible practical modification is to use the fraction of the start-up retained by the VC instead. For example, because the best VCs choose $c^{*,Unc} = (0.325, 1, 0, 1)$, the post-money valuation of their start-up, per dollar of capital invested, would be $\frac{\$1}{0.325} = \$3.08$. In contrast, because the best VCs retain 50.3% of the total value, the modified valuation would instead be $\frac{\$1}{0.503} = \$1.99$, a 35.4% 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 the split of value across deals completed by different quartiles of investor and entrepreneur qualities. Deals completed by top 25% of investors are, on average, twice as large as deals completed by bottom 25% of investors. Bottom 25% of 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 investor quality: most high-value deals are signed by top 25% of entrepreneurs. The VC share of the total value increases with its quality and decreases with entrepreneur quality.

Returning to coefficient estimates, frequencies of investor and entrepreneur encounters suggest that an investor meets a entrepreneur of a sufficiently high quality, on average, every $\frac{1}{7.730} = 47$ days, while such an entrepreneur meets an investor, on average, every $\frac{1}{7.041} = 52$ days. Panel B of Table VIII shows that these frequencies of encounters, combined with less interpretable estimates of quality distributions, result in investors (entrepreneurs) signing deals, on average, every $\frac{1}{1.320} = 277$ ($\frac{1}{1.202} = 304$) days. Lower-quality investors are more active but less selective in deal signing: bottom 25% sign a deal, on average, every 243 days, while top 25% – every 295 days. The opposite is true for entrepreneurs: bottom 25% rarely sign a deal, while top 25% sign it, on average, in 88 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 and its segments. To obtain these, we need to know measures of investors and entrepreneurs in the market. In equilibrium, measures of encounters by the counterparties have to be equal: $\lambda_i m_i = \lambda_e m_e$, which gives the ratio of measures of entrepreneurs to investors as $\frac{m_e}{m_i} = \frac{\lambda_i}{\lambda_e}$. On a per-investor basis, then, the present value of all deals in the market is the sum, across all i and e with appropriate probability weights, of $V_i(i) + \frac{m_e}{m_i} V_e(e)$. Panel C of Table VIII shows that overall, investors retain 73.01% of the present value of all deals in the market. Bottom 25% of investors retain 11.63% of this value, while top 25% retain 26.17%. In contrast, bottom 25% of entrepreneurs retain almost no value, while top 25% retain value comparable to top 25% of investors: 22.24%. In the next section, we examine the impact of the potential changes to 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 value of a start-up, frequency of deals, and the present value of all deals in the market. The particular focus is on regulating the contracting environment, seeing as how the inclusion of certain features into the contract can benefit VCs at the expense of the total value.[25] Additionally, we examine the effect of lowering search frictions (e.g., via introducing a centralized platform akin to AngelList, where investors and entrepreneurs can easily encounter each other).

5.1 Contractual Features

The naive approach to examine the effect of a removal of contractual features on deal outcomes would be to simply remove features in each deal, in which they are present, and then re-calculate the total value and its split. Unfortunately, the naive approach is incorrect because it is off-equilibrium: in the new market equilibrium, agents would rebalance contract terms that implement the remaining features and match in a different pattern. Panel A of Table IX shows the equilibrium effect of removing contractual features on the total value and its split. We analyze both the sample of all deals and deals done by various quartiles of investor and entrepreneur quality. We also decompose the aggregate equilibrium effect into two partial effects. The first effect, that of rebalancing, occurs when we only allow agents to rebalance contract terms that implement the remaining features to keep each entrepreneur's expected present value $V_e(e)$ unaffected, so that its participation constraint remains satisfied. At the same time, we do not allow agents to match differently. Note that the first effect alone is off-equilibrium, because at least some investors, whose expected present value $V_i(i)$ would be affected by a removal of contractual features, would have incentives to rematch. However, this effect helps understand the impact of features on the firm in autarky, in the absence of market effects. The second effect, that of rematching, occurs

[25] Note that because we do not explicitly model mechanisms, through which contractual features affect the value, we are unable to examine the effect of including an contractual feature. For the same reason, we are unable to examine the effect of regulating contractual features that are always present, such as debt-like features captured by 1X liquidation preference (although there is variation in this term in later-round financings). We can only examine the effect of regulating the existing features that vary in the sample, such that post-regulation features stay within the set of realized features in the sample. It is important to add that while we study the effect of a removal of certain contracting terms from the contracting environment, our results should be interpreted as a study of a regulation of contracting features that these terms implement (e.g., "double-dipping", which is typically implemented via participation preference but can also be implemented differently). If, instead, one simply regulates terms but not contracting features, a VC can often work around this regulation via a different implementation of a feature.

when we allow agents to both rebalance contract terms that implement the remaining features and match differently.

Panel A of Table IX shows that the effect of rebalancing on both the total value and its split is uniformly negative and small across deals. For example, if contractual features implemented by both participation preference and the VC board seat are regulated, rebalancing alone is responsible for a 0.29% decrease of the average, across all deals, total value compared to its pre-regulation level. In the absence of market effects, to keep paying the entrepreneur its pre-regulation expected present value $V_e(e)$, the VC replaces VC-friendly regulated features with other VC-friendly terms. However, these terms have a more detrimental effect on the total value and the VC share of it than regulated features, decreasing both post-regulation. The effect of rematching due to a removal of VC-friendly features, on the other hand, is positive and large across deals. For example, if contractual features implemented by both participation preference and VC board seat are regulated, the aggregate equilibrium effect is responsible for a 0.87% increase in the average, across all deals, total value, implying that rematching alone is responsible for a 1.16% increase. As for the split of value, the aggregate equilibrium effect is responsible for a 1.65% decrease (2.52% increase) of the VC's (entrepreneur's) average, across all deals, value computed in units of the pre-regulation total value, implying that rematching alone is responsible for a 1.36% decrease (2.52% increase). For a complementary view on the magnitude of the aggregate equilibrium effect, note that a 1.65% decrease (2.52% increase) of the VC's (entrepreneur's) average value computed in units of the pre-regulation total value corresponds to a 3.58% decrease (4.69% increase) computed in units of the pre-regulation VC's (entrepreneur's) value. At the same time, the effect of rematching due to a removal of entrepreneur-friendly features is negative and large. If contractual features implemented by pay-to-play are regulated, the aggregate equilibrium effect is responsible for a 1.88% decrease in the average, across all deals, total value, implying that rematching alone is responsible for a 1.85% decrease. As for the split of value, the aggregate equilibrium effect is responsible for a 0.48% decrease (1.40% decrease) of the VC's (entrepreneur's) average, across all deals, value computed in units of the pre-regulation total value, implying that rematching alone is responsible for a 0.45% decrease (1.40% decrease).

While the effect of rebalancing is uniformly negative, the effect of rematching changes across deals. For example, if contractual features implemented by both participation preference and VC board seat are regulated, the effect of rematching on the total value is negative (positive) and large for bottom 25% of VCs (all but bottom 25% of VCs and entrepreneurs). For top 25% of VCs (entrepreneurs), the aggregate equilibrium effect is responsible for a 4.36% (4.12%) increase in the average, across deals done by such agents, total value compared to its pre-regulation level; the same effect for 25-50% range of entrepreneurs is 127.56%. The effect of rematching on the split of value is negative for all VCs and positive for all but bottom 25% of entrepreneurs. At the same time, if contractual features implemented by pay-to-play are regulated, the effect of rematching on the total value is negative (positive) and large for bottom 25% of VCs (all but bottom 25% of entrepreneurs) and zero for all but bottom 25% of VCs. In particular, for top 25% of entrepreneurs, the aggregate equilibrium effect is responsible for a 0.37% increase in the average, across deals done by such agents, total value compared to its pre-regulation level; the same effect for 25-50% range of entrepreneurs is 54.00%. The effect of rematching on the split of value is negative for bottom 25% of VCs and positive for all but bottom 25% of entrepreneurs.

To better understand the intuition behind the effect of rematching, 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 preference and VC board seat are regulated, deals, on average, become 4.33% more frequent. This increase is due to a substantial increase in deal frequencies by bottom 25% of investors, who make 13.53% more deals than pre-regulation. They appear to match with lower-quality entrepreneurs: top 25% (25-50% range) of entrepreneurs see 1.33% fewer (1050.67%) more deals than pre-regulation. Interestingly, a similar pattern but on a smaller scale appears if contractual features implemented by pay-to-play are regulated instead.

The combined intuition behind these results is as follows. In equilibrium, VC-friendly features are offered by the best VCs, while entrepreneur-friendly features are offered by the worst VCs in a block. A removal of VC-friendly features, despite rebalancing of contract 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 do not match with the worst VCs in their block post-regulation. This, in turn, leads to lower continuation values for the worst VCs in the block, who have to match with worse entrepreneurs post-regulation. This rebalancing effect snowballs down the ladder of VC and entrepreneur qualities, resulting in the VCs losing and the entrepreneurs (especially the worst overall entrepreneurs, who rarely match pre-regulation but see a dramatic increase in their matching rates with the worst overall VCs) winning from the removal of VC-friendly features, with more valuable deals overall. 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 who previously matched with them, and hence choose to match with worse entrepreneurs post-regulation. This, in turn, leads to lower continuation values of entrepreneurs who previously matched with such VCs. This rebalancing effect snowballs down the ladder of qualities, resulting in *both* the VCs and entrepreneurs losing from the removal of entrepreneur-friendly features, with less valuable deals overall.

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. Whether VC- or entrepreneur-friendly features are regulated, the change, relative to the pre-regulation present value of all deals, is positive and ranges from 0.33% when only features implemented by the VC board seat are regulated to 4.73% when features implemented by both participation preference and the VC board seat are regulated. At the same time, the expected present value of VCs (entrepreneurs) uniformly decreases (increases) across various ranges of qualities. For example, if contractual features implemented by both participation preference and the VC board seat are regulated, VCs on average lose 1.16% of the present value computed in units of the pre-regulation present value of all deals, while entrepreneurs gain 5.89%. Bottom 25% (top 25%) of VCs (entrepreneurs) are affected the most, losing 0.48% (gaining 2.88%) of the present value computed in units of the pre-regulation present value of all deals. For a complementary view on the magnitude of regulation on present values, note that a 1.16% decrease (5.89% increase) of the expected present value across all VCs (entrepreneurs) computed in units of the pre-regulation present value of all deals corresponds to a 1.58% decrease (21.81% increase) computed in units of the pre-regulation present value across all VCs (entrepreneurs). The result that a removal of entrepreneur-friendly contractual features implemented by pay-to-play decreases the expected present value of all deals in the market may appear counterintuitive. Note however that the expected present value combines deal values with deal frequencies. While the average deal value decreases in the absence of entrepreneur-friendly features, more deals occur in the new equilibrium, overcoming the deal value effect in the present value of all deals.

The high magnitude and heterogeneity of the rematching effect across deals, as well as its subtle impact on the value of the VC market, suggests that selection of VCs and entrepreneurs into deals is a major factor to take into account if one is concerned about regulation of contractual features in this market. While it may not be surprising that a removal of VC-friendly features transfers deal value from VCs to entrepreneurs, the substantial asymmetry of the transfer, due to value creation, suggests that regulation of at least the most VC-friendly features (such as "double-dipping" implemented by participation preference) should be considered by policy makers. One concern with our results is that, while we consider a general equilibrium in the VC market, agents in this market have other opportunities outside of it and can leave, or additional agents can enter, following regulation. Because the negative impact on VCs is limited but the positive effect on entrepreneurs is strong, it is more likely that the combined effect of regulation of VC contracts would add more value in newly participating entrepreneurs than lose value in departing VCs.

5.2 Search Frictions

How will the present value of all deals in the market change if the counterparties are able to find each other faster? Who benefits from the decrease in search frictions, VCs or entrepreneurs? Answers to these questions are not immediately clear, yet they can be important for policy makers concerned with centralizing the search process via, for example, a platform similar to AngelList for angel investors. In this section, we examine the effect of low search frictions on 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. A moderate decrease in frictions ($2X$) leads to a 2.13% decrease in the expected present value of all deals computed in units of the estimated present value of all deals. Entrepreneurs lose 7.18%, while VCs gain 5.05%. Best entrepreneurs (VCs) lose (gain) 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 lose 16.21%, while VCs gain 14.46%.

The intuition behind this result is as follows. Armed with more bargaining power than entrepreneurs, VCs benefit more from a decrease in search costs and hence an increase in their expected present value of deals. In turn, they become more selective in their matching, choosing better entrepreneurs post-regulation. This effect appears to be particularly strong for the best overall VCs, who do not settle on anything but best overall entrepreneurs. As a result, the expected present value of all, including top 25% of entrepreneurs (many of whom lose an opportunity to match with the best overall VCs post-regulation), decreases.

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.

The exercise in this section is also useful to assess bias if selection were modeled as a static matching model with no search frictions. Adachi (2003, 2007) shows that when λ_i and λ_e are very high, our model converges to a one-shot static matching model. Direct estimation of our model when λ_i and λ_e are exogenously set high is difficult[26]. However, since value is split very differently between counterparties in the low- versus high-friction environment, it is likely that the estimates obtained from this model modification would be very different. This insight underlines the importance of modeling search frictions in the VC market.

[26] 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.

6 Robustness and Extensions

Our results are robust to various model modifications. We discuss in detail the most interesting robustness checks and refer the reader to Appendix E for additional robustness checks outlined in the final subsection.

6.1 Matching Function

The degree of complementarity between the counterparties in a start-up is typically unknown. Therefore a concern can be that the impact of contract terms is estimated incorrectly because the impact of qualities i and e on the expected 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):

$$\pi(i, e, c^*) = \left(\sum_{j \in \{i,e\}} \frac{1}{2} j^{2\rho} \right)^{\frac{1}{\rho}} \cdot h(c^*). \tag{14}$$

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: ρ is estimated at -1.71. This complementarity mainly shifts γ_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 γ_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.

6.2 Overconfidence

There is ample evidence that entrepreneurial individuals are overconfident, i.e., assign a higher precision to their information than the data would suggest.[27] Our model is easily extendable to

[27] Theoretical and empirical research on entrepreneural overconfidence includes Cooper, Woo, and Dunkelberg (1988) and Bernardo and Welch (2001).

allow for overconfidence on the part of agents. Modify (5) and (6) as

$$\pi_i^j(i,e,c^*) = \alpha(c^*)\cdot\pi^j(i,e,c^*), \tag{15}$$

$$\pi_e^j(i,e,c^*) = (1-\alpha(c^*))\cdot\pi^j(i,e,c^*), \tag{16}$$

where superscript $j \in \{i,e\}$ indicates that investors 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, $\pi^j(i,e,c^*) = i\cdot(p_je+(1-p_j)\bar{e})\cdot h(c^*)$. 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

$$c^*(i,e) = \underset{c\in C:\pi_e^e(i,e,c)\geq V_e(e)}{\arg\max}\ \pi_i^i(i,e,c). \tag{17}$$

Note that even though the investor 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.

6.3 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

$$h(c^*) = \exp\left\{\beta_0 \log c_0^* + \beta_1 c_1^* + \beta_2 c_1^{*2} + \beta_{3:D+1}'(1-c_1^*)c_{2:D}^*\right\}, \tag{18}$$

and modify (5) as

$$\pi_i(i,e,c^*) = \phi(c_0^*) \cdot \alpha(c^*) \cdot \pi(i,e,c^*), \tag{19}$$

keeping (6) unchanged. Equation (18) implies that the matching function in the presence of endogenous investment exhibits returns to scale with factor β_0. Equation (19) implies that an investor 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 $\phi(c_0^*) = \exp\{\gamma_0 c_0^*\}$.[28]

The model with endogenous investment (an additional continuous contract term) is very computationally complex, therefore we do not attempt to estimate it. Instead, we examine its comparative statics with respect to 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 investors 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.[29] In turn, it is unlikely that the impact of other contract terms on deal values and their split would be substantially affected.

6.4 Exogenous Shocks

Two key results of the main model is that the set of counterparties an investor 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

[28]It is easy to justify the positive relationship between total costs of investment and the investor's share of the start-up via a simple model. See, e.g., Grossman and Hart (1986).

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

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 investor at the same contract, or with the same investor 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 $\lambda_{e,x}$. In Appendix F we derive theoretical moments to estimate this extension via the GMM. 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]

6.5 Discussion of Other Assumptions

In addition to the robustness checks outlined above, our results are robust to (a) high risk-aversion of counterparties (higher r); (b) additional bargaining power on the part of entrepreneurs in contract negotiations; (c) the presence of submarkets (e.g., different geographical locations and industries) with different distributions of agents' qualities and encounter frequencies; (d) using contract data in 2002–2015 and treating exit outcomes in 2009–2015 as truncated data; (e) finer 51 point grid of VC and entrepreneur qualities; (f) non-optimal GMM weighting matrix (i.e., diagonal).

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 counterparties' 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

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. 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. 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

$$V_i(i) = \frac{1}{1+rdt}\left(\lambda_i dt\left(\int_{e\in\mu_i(i)} \max\left\{\pi_i(i,e,c^*),V_i(i)\right\}dF(e) + \int_{e\notin\mu_i(i)} V_i(i)dF(e)\right) + (1-\lambda_i dt)V_i(i)\right), \quad (20)$$

$$V_e(e) = \frac{1}{1+rdt}\left(\lambda_e dt\left(\int_{i\in\mu_e(e)} \max\left\{\pi_e(i,e,c^*),V_e(e)\right\}dF(i) + \int_{i\notin\mu_e(e)} V_e(e)dF(i)\right) + (1-\lambda_e dt)V_e(e)\right) \quad (21)$$

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

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

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

B 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.[30] 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.[31] We stop the process when $\|V^n - V^{n-1}\| < \varepsilon$, where $\varepsilon > 0$ is sufficiently small.

[30] 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.

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

C 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.

C.1 Contract-related moments

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

$$E(c_k^*) = \frac{\sum_i \sum_e w_i w_e m(i,e) c_k^*(i,e)}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{22}$$

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

$$V(c_k^*) = \frac{\sum_i \sum_e w_i w_e m(i,e)(c_k^*(i,e) - E(c_k^*))^2}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{23}$$

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

$$Cov(c_k^*, c_l^*) = \frac{\sum_i \sum_e w_i w_e m(i,e)(c_k^*(i,e) - E(c_k^*)) \cdot (c_l^*(i,e) - E(c_l^*))}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{24}$$

C.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

$$E(\tau|i) = \frac{1}{\lambda_i p_i}; \quad V(\tau|i) = \frac{1}{(\lambda_i p_i)^2}. \tag{25}$$

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 (25),

$$E(\tau) = \frac{\sum_i \sum_e w_i w_e m(i,e) \frac{1}{\lambda_i p_i}}{\sum_i \sum_e w_i w_e m(i,e)}. \tag{26}$$

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

$$V(\tau) = E[V(\tau|i)] + V[E(\tau|i)]. \tag{27}$$

Using (25), the first term of (27) 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 (26), 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,

$$Cov(\tau, c_k^*) = E[Cov(\tau, c_k^*|i)] + Cov[E(\tau|i), E(c_k^*|i)] \tag{28}$$

The first term of (28) is zero, because the time between deals does not vary with contract terms for a given investor. Using (22), (25), (26), 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

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

C.3 IPO-related moments

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

$$Pr(IPO = 1|i,e) = \Phi(\kappa_0 + \kappa_1 \cdot \pi(i,e,c^*(i,e))), \tag{29}$$

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

$$\begin{aligned} E(IPO) &= E\left[E(IPO = 1|i,e)\right] \\ &= E\left[Pr(IPO = 1|i,e)\right] \\ &= \frac{\sum_i \sum_e w_i w_e m(i,e) \Phi(\theta_0 + \theta_1 \cdot \pi(i,e,c^*(i,e)))}{\sum_i \sum_e w_i w_e m(i,e)}. \end{aligned} \tag{30}$$

Similarly to (27), because IPO is random for any given deal, its variance is, from the law of total variance,

$$\begin{aligned} V(IPO) &= E(V(IPO|i,e)) + V(E(IPO|i,e)) \\ &= E(Pr(IPO=1|i,e)\cdot(1-Pr(IPO=1|i,e))) + V(Pr(IPO=1|i,e)) \\ &= \frac{\sum_i\sum_e w_i w_e m(i,e)\Phi(\theta_0+\theta_1\cdot\pi(i,e,c^*(i,e)))\cdot(1-\Phi(\theta_0+\theta_1\cdot\pi(i,e,c^*(i,e))))}{\sum_i\sum_e w_i w_e m(i,e)} \\ &\quad + \frac{\sum_i\sum_e w_i w_e m(i,e)(\Phi(\theta_0+\theta_1\cdot\pi(i,e,c^*(i,e)))-E(IPO))^2}{\sum_i\sum_e w_i w_e m(i,e)}, \end{aligned} \tag{31}$$

where we use (29) and (30) 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

$$\begin{aligned} Cov(IPO, c^*_k) &= E(Cov(IPO, c^*_k|i,e)) + Cov(E(IPO|i,e), E(c^*_k|i,e)) \\ &= Cov(Pr(IPO|i,e), c^*_k(i,e)) \\ &= \frac{\sum_i\sum_e w_i w_e m(i,e)(\Phi(\theta_0+\theta_1\cdot\pi(i,e,c^*(i,e)))-E(IPO))\cdot(c^*_k(i,e)-E(c^*_k))}{\sum_i\sum_e w_i w_e m(i,e)}, \end{aligned} \tag{32}$$

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 (22), (29), and (30).

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

$$\begin{aligned} Cov(\tau, IPO) &= E[Cov(\tau, IPO|i)] + Cov[E(\tau|i), E(IPO|i)] \\ &= Cov[E(\tau|i), E(IPO|i)] \\ &= \sum_i w_i[E(\tau|i)-E(\tau)]\cdot[E(IPO|i)-E(IPO)] \\ &= \frac{\sum_i\sum_e w_i w_e m(i,e)\left(\frac{1}{\lambda_i p_i}-E(\tau)\right)\cdot(\Phi(\theta_0+\theta_1\cdot\pi(i,e,c^*(i,e)))-E(IPO))}{\sum_i\sum_e w_i w_e m(i,e)}, \end{aligned} \tag{33}$$

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 (25), (26), (29), (30), and $E(IPO|i) = \frac{\sum_e w_e m(i,e) Pr(IPO|i,e)}{\sum_i\sum_e w_i w_e m(i,e)} = \frac{\sum_e w_e m(i,e)\Phi(\theta_0+\theta_1\cdot\pi(i,e,c^*(i,e)))}{\sum_i\sum_e w_i w_e m(i,e)}$.

D 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.[32]

E Additional robustness checks

E.1 Risk Aversion and Discount Factor

A standard assumption in both empirical finance and industrial organization literature is that the researcher knows the discount rate r[33], so we set it at 10% in our model. However, it is likely that at least entrepreneurs are more risk-averse and discount future heavier than large firms, for which this assumption is typically made. We change the entrepreneurs' r to 20% and compare the estimates to those of our main model. [RESULTS TO BE ADDED]

E.2 Bargaining Power

Entrepreneurs' 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 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 $\gamma = 0.1$.[34]

[32] 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: $\frac{\partial \pi_i\left(i,e,c^*(i,e)\right)}{\partial i \partial e} < 0$ (see Theorem 1 in Smith (2011)).

[33] See, e.g., Strebulaev, Whited, et al. (2012) and Bajari, Benkard, and Levin (2007).

[34] 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

[RESULTS TO BE ADDED]

E.3 Multiple Markets

The VC market is segmented, so that entrepreneurs and investors 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 the IPO outcomes 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]

E.4 Truncated Exit Data

In the main model, we restrict our final sample to 2002–2009 to allow start-ups formed in this period to exit before June 2017, the end of our outcome observation period. While all exits for financings close in 2009–2015 are unlikely to be completed, this period could still contain potentially useful information on other deal outcomes, such as contract terms. It would then be useful to incorporate this information in our estimates. Lynch and Wachter (2013) develop an augmented moments estimator that helps account for the presence of truncated exit data in our case. Out results are robust to using this estimator. [RESULTS TO BE ADDED]

F Derivation of theoretical moments for the model with exogenous shocks

Consider investor i (the case of an entrepreneur is symmetric). Let ρ_x be the frequency with which the state of the economy exits $x \in \{0,1\}$. This state can affect populations of agents and frequencies of encounters: $\lambda_{j,x}$ and $F_{j,x}(j)$, $j \in \{i,e\}$. The agents' expected present values, $V_i(i,x)$, now depend on the state of the economy and are

$$\begin{aligned}
V_i(i,0) &= \tfrac{1}{1+rdt} \left(\lambda_{i,0}dt\left(\int_{e\in\mu_i(i,0)} \max\{\pi_i(i,e,c^*),V_i(i,0)\}dF_0(e) + \int_{e\notin\mu_i(i,0)} V_i(i,0)dF_0(e)\right)\right.\\
&\quad \left. + \rho_0 dt V_i(i,1) + (1-(\lambda_{i,0}+\rho_0)dt)V_i(i,0)\right);\\
V_i(i,1) &= \tfrac{1}{1+rdt} \left(\lambda_{i,1}dt\left(\int_{e\in\mu_i(i,1)} \max\{\pi_i(i,e,c^*),V_i(i,1)\}dF_1(e) + \int_{e\notin\mu_i(i,1)} V_i(i,1)dF_1(e)\right)\right.\\
&\quad \left. + \rho_1 dt V_i(i,0) + (1-(\lambda_{i,1}+\rho_1)dt)V_i(i,1)\right).
\end{aligned}$$

Transformations similar to those in the proof of Proposition 1 lead to

$$\begin{aligned}
V_i(i,0) &= \frac{\lambda_{i,0}}{r+\lambda_{i,0}+\rho_0}\left(\int_e \max\left\{\mathbf{1}_{e\in\mu_i(i,0)}\pi_i(i,e,c^*),V_i(i,0)\right\}dF_0(e) + \frac{\rho_0}{\lambda_{i,0}}V_i(i,1)\right);\\
V_i(i,1) &= \frac{\lambda_{i,1}}{r+\lambda_{i,1}+\rho_1}\left(\int_e \max\left\{\mathbf{1}_{e\in\mu_i(i,1)}\pi_i(i,e,c^*),V_i(i,1)\right\}dF_1(e) + \frac{\rho_1}{\lambda_{i,1}}V_i(i,0)\right).
\end{aligned}$$

quantitatively unaffected.

Solving for $V(i,x)$, $x \in \{0,1\}$, we obtain a discrete-time representation

$$\begin{aligned}
V_i(i,0) &= \frac{\lambda_{i,0}(r+\lambda_{i,1}+\rho_1)}{(r+\lambda_{i,0}+\rho_0)(r+\lambda_{i,1}+\rho_1)-\rho_0\rho_1}\int_e \max\left\{\mathbf{1}_{e\in\mu_i(i,0)}\pi_i(i,e,c^*),V_i(i,0)\right\}dF_0(e)\\
&+ \frac{\rho_0\lambda_{i,1}}{(r+\lambda_{i,0}+\rho_0)(r+\lambda_{i,1}+\rho_1)-\rho_0\rho_1}\int_e \max\left\{\mathbf{1}_{e\in\mu_i(i,1)}\pi_i(i,e,c^*),V_i(i,1)\right\}dF_1(e);\\
V_i(i,1) &= \frac{\lambda_{i,1}(r+\lambda_{i,0}+\rho_0)}{(r+\lambda_{i,0}+\rho_0)(r+\lambda_{i,1}+\rho_1)-\rho_0\rho_1}\int_e \max\left\{\mathbf{1}_{e\in\mu_i(i,1)}\pi_i(i,e,c^*),V_i(i,1)\right\}dF_1(e)\\
&+ \frac{\rho_1\lambda_{i,0}}{(r+\lambda_{i,0}+\rho_0)(r+\lambda_{i,1}+\rho_1)-\rho_0\rho_1}\int_e \max\left\{\mathbf{1}_{e\in\mu_i(i,0)}\pi_i(i,e,c^*),V_i(i,0)\right\}dF_0(e).
\end{aligned}$$

so that same solution techniques as in the base model apply.

The expressions for the theoretical moments related to expected time between deals change in the presence of the change in the state of the economy. The easiest way to compute these is via Bellman equations. For $E[\tau|i,x]$,

$$\begin{aligned}
\lambda_{i,0}p_{i,0}E[\tau|i,0] &= \lambda_{i,0}p_{i,0}E[\tau|i,\text{always }0]+\rho_0\left(E[\tau|i,1]-E[\tau|i,0]\right);\\
\lambda_{i,1}p_{i,1}E[\tau|i,1] &= \lambda_{i,1}p_{i,1}E[\tau|i,\text{always }1]+\rho_1\left(E[\tau|i,0]-E[\tau|i,1]\right),
\end{aligned}$$

where, similarly to (25), expected times under the assumption that the state of the economy never changes are equal to $E[\tau|i,\text{always }0]=\frac{1}{\lambda_{i,0}p_{i,0}}$ and $E[\tau|i,\text{always }1]=\frac{1}{\lambda_{i,1}p_{i,1}}$. Intuitively, the expected time in the presence of the change in the state of the economy is the expected time in the absence of the change (the first term on the right-hand side), corrected for the possibility of the change, at which point the expected time switches to a different value reflecting the change (the second term on the right-hand side). The solution is

$$\begin{aligned}
E[\tau|i,0] &= \frac{\lambda_{i,1}p_{i,1}+\rho_1+\rho_0}{(\lambda_{i,0}p_{i,0}+\rho_0)(\lambda_{i,1}p_{i,1}+\rho_1)-\rho_0\rho_1};\\
E[\tau|i,1] &= \frac{\lambda_{i,0}p_{i,0}+\rho_0+\rho_1}{(\lambda_{i,0}p_{i,0}+\rho_0)(\lambda_{i,1}p_{i,1}+\rho_1)-\rho_0\rho_1}.
\end{aligned}$$

Similarly, the expected squared time between deals, $E[\tau^2|i,x]$, is obtained from

$$\begin{aligned}
\lambda_{i,0}p_{i,0}E[\tau^2|i,0] &= \lambda_{i,0}p_{i,0}E[\tau^2|i,\text{always }0]+\rho_0\left(E[\tau^2|i,1]-E[\tau^2|i,0]\right);\\
\lambda_{i,1}p_{i,1}E[\tau^2|i,1] &= \lambda_{i,1}p_{i,1}E[\tau^2|i,\text{always }1]+\rho_1\left(E[\tau^2|i,0]-E[\tau^2|i,1]\right),
\end{aligned}$$

where, similarly to (25), $E[\tau^2|i,\text{always }0]=\frac{2}{(\lambda_{i,0}p_{i,0})^2}$ and $E[\tau|i,\text{always }1]=\frac{2}{(\lambda_{i,0}p_{i,0})^2}$. The solution is

$$\begin{aligned}
E[\tau^2|i,0] &= \frac{\frac{2}{\lambda_0 p_{i,0}}(\lambda_{i,1}p_{i,1}+\rho_1)+\frac{2}{\lambda_1 p_{i,1}}\rho_0}{(\lambda_{i,0}p_{i,0}+\rho_0)(\lambda_{i,1}p_{i,1}+\rho_1)-\rho_0\rho_1};\\
E[\tau^2|i,1] &= \frac{\frac{2}{\lambda_1 p_{i,1}}(\lambda_{i,0}p_{i,0}+\rho_0)+\frac{2}{\lambda_0 p_{i,0}}\rho_1}{(\lambda_{i,0}p_{i,0}+\rho_0)(\lambda_{i,1}p_{i,1}+\rho_1)-\rho_0\rho_1}.
\end{aligned}$$

The variance of time between deals, $V[\tau^2|i,x]$, is equal to $E[\tau^2|i,x]-(E[\tau|i,x])^2$. Covariances of time between deals and other outcome variables in each state of the world are computed as in Appendix C, taking into account new expressions for $E[\tau|i,x]$. The expressions for the remaining theoretical moments are not affected by the presence of x (however, their values in different states of the world can be different, because discretized probabilities of encounters, $w_{i,x}$ and $w_{e,x}$, can change).

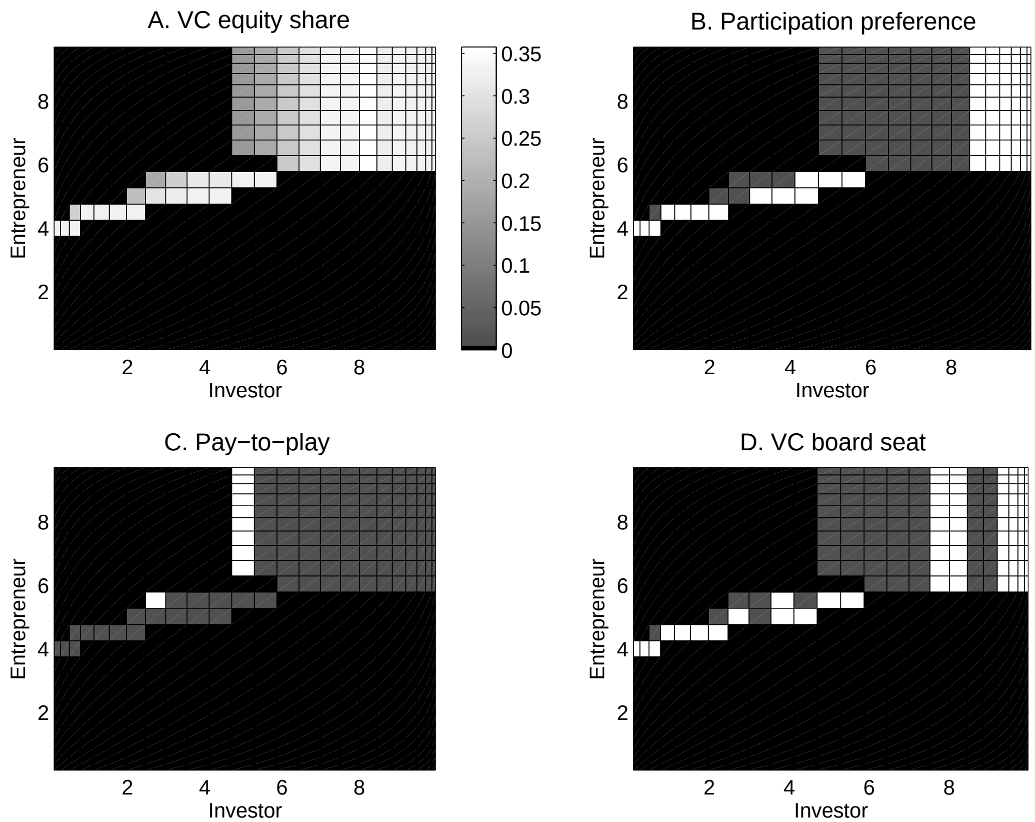

Figure 1: **Equilibrium contract terms for estimated model parameters.** For each combination of investor and entrepreneur quality, Panel A shows VC equity share, Panel B shows participation preference, Panel C shows pay-to-play, and Panel D shows the VC board seat. Combinations that do not form a start-up are shown in black. VC equity share takes values in $[0, 1]$ and is shown in greyscale. In particular, the unconstrained VC-optimal contract, $c^* = (0.325, 1, 0, 1)$, includes 32.5% VC equity. Participation preference, pay-to-play and the VC board seat take values in $\{0, 1\}$, and their inclusion is shown in white.

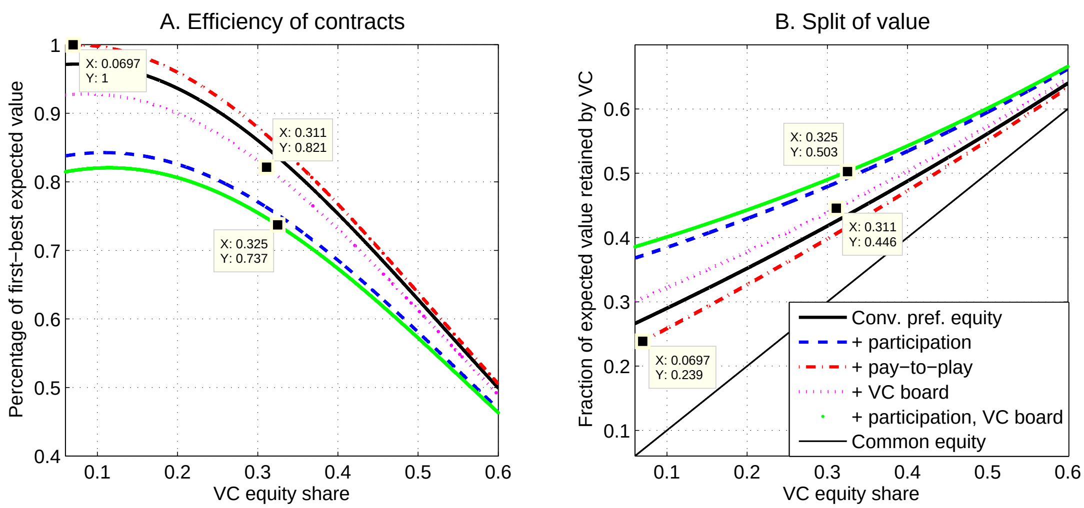

Figure 2: **Impact of contract terms on total value and its split.** For reasonable values of VC equity share, $c_1 \in [0.06, 0.6]$, and for various combinations of participation preference, pay-to-play, and the VC board seat that occur in equilibrium, Panel A shows the ratio of the total value created in a start-up to the first-best value; Panel B shows the fraction of the total value retained by the VC. Datatips show the impact of the first-best contract, $c^{FB} = (0.070, 0, 1, 0)$, the average contract, $c^{*,Avg} = (0.311, 0, 0, 1)$, and the unconstrained VC-optimal contract, $c^{*,Unc} = (0.325, 1, 0, 1)$, on the total value and split.

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 statististics 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: Start-up outcomes, initial contract and equity terms.

Notes: The table reports linear probability regression estimation where the dependent variable is an exit outcome for start-up financed before 2010. "IPO" is equal to one if the start-up has a public offering. The sample includes all startups where we can observe the full assortment of contract terms. "% equity sold to investors" is the total (as-if-common) equity stake sold in the startup's first round financing. "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: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	IPO						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
% equity sold to investors	0.218***	0.174***	0.188***	0.159***	0.124***	0.137***	0.103*
	(0.0412)	(0.0321)	(0.0471)	(0.0405)	(0.0314)	(0.0491)	(0.0525)
Participating pref.	-0.0395***			-0.0398***			-0.0459**
	(0.0129)			(0.0139)			(0.0178)
VC has board seat		0.0309***			0.0330***		0.0433**
		(0.0112)			(0.0109)		(0.0200)
Pay to play			0.0676**			0.0497*	0.0517*
			(0.0298)			(0.0301)	(0.0310)
Log raised							0.0169*
							(0.00931)
Constant	0.0121	-0.0272*	0.0123	0.0480	-0.147**	-0.203***	-0.0388
	(0.0181)	(0.0142)	(0.0197)	(0.0526)	(0.0589)	(0.0671)	(0.103)
Observations	2118	2956	1487	2118	2956	1487	1456
R^2	0.0208	0.0167	0.0209	0.0303	0.0311	0.0273	0.0356
Year FE	N	N	N	Y	Y	Y	Y
Year founded FE	N	N	N	Y	Y	Y	Y
State FE	N	N	N	Y	Y	Y	Y
Industry FE	N	N	N	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.

Moment	Empirical	Theoretical
Avg. time since last VC financing	0.7870	0.7576
Var. time since last VC financing	1.7408	0.5923
Avg. share of VC equity	0.3523	0.3109
Var. share of VC equity	0.0306	0.0018
Cov. time since last VC financing and share of VC equity	0.0064	0.0012
Avg. participation preference	0.4094	0.4951
Cov. time since last VC financing and participation preference	0.0563	-0.0064
Cov. share of VC equity and participation preference	0.0222	0.0066
Avg. pay-to-play	0.1043	0.0298
Cov. time since last VC financing and pay-to-play	0.0068	-0.0033
Cov. share of VC equity and pay-to-play	0.0154	-0.0045
Cov. participation preference and pay-to-play	0.0241	-0.0148
Avg. VC board seat	0.6187	0.5004
Cov. time since last VC financing and VC board seat	-0.0058	-0.0032
Cov. share of VC equity and VC board seat	0.0144	0.0100
Cov. participation preference and VC board seat	0.0151	0.0497
Cov. pay-to-play and VC board seat	0.0079	-0.0149
Avg. IPO rate	0.0466	0.0155
Cov. time since last VC financing and IPO rate	-0.0063	0.0004
Cov. share of VC equity and IPO rate	0.0073	0.0001
Cov. participation preference and IPO rate	-0.0022	0.0003
Cov. pay-to-play and IPO rate	0.0100	-0.0001
Cov. VC board seat and IPO rate	0.0074	0.0001

Table VII: Parameter estimates.

Notes: The table describes parameter estimates of the model described in Section 5.2. Significance: ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$.

Parameter	Estimate	Standard error
Distribution of qualities, a_i	3.2530***	0.3335
Distribution of qualities, b_i	1.2639**	0.4565
Distribution of qualities, a_e	7.7300***	0.3269
Distribution of qualities, b_e	5.5347***	0.2264
Frequency of encounters, λ_i	7.6921***	0.1063
Frequency of encounters, λ_e	7.0405***	0.0413
Probability of IPO, intercept, κ_0	-2.7047	2.2567
Probability of IPO, total value, κ_1	0.0148	0.0549
Total value, share of VC equity, β_1	0.3695***	0.0041
Total value, share of VC equity squared, β_2	-2.4267***	0.0416
Total value, participation preference, β_3	-0.1572***	0.0138
Total value, pay-to-play, β_4	0.0308	0.0696
Total value, VC board seat, β_5	-0.0500	0.0984
Total value, part. pref. $\times$ pay-to-play, β_6	0.0121	0.0437
Total value, part. pref. $\times$ VC board seat, β_7	0.0201**	0.0077
Total value, pay-to-play $\times$ VC board seat, β_8	0.0123	0.0435
Split of value, intercept, γ_1	-0.2635***	0.0041
Split of value, participation preference, γ_2	-0.1590***	0.0441
Split of value, pay-to-play, γ_3	0.0482	0.0518
Split of value, VC board seat, γ_3	-0.0516	0.0812
Split of value, part. pref. $\times$ pay-to-play, γ_5	0.0096	0.0329
Split of value, part. pref. $\times$ VC board seat, γ_6	0.0217	0.0342
Split of value, pay-to-play $\times$ VC board seat, γ_7	0.0105	0.0542

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

Notes: Panel A of the table reports expected total value and split of value across all deals and deals completed by quartiles of investor and entrepreneur qualities. Expected total values in quartile subsamples, $\pi^*(Sub)$, are percentages of expected total value across all deals, $\pi^*(All)$. Expected values of investors and entrepreneurs across all deals and in quartile subsamples, $\pi_j^*(All)$ and $\pi_j^*(Sub)$, $j \in \{i, e\}$, are percentages of expected total value in the relevant subsample, $\pi^*(All)$ and $\pi^*(Sub)$ correspondingly. Panel B of the table reports expected deal frequencies across all market participants, $\Lambda_j(All)$, and by quartiles of investor and entrepreneur qualities, $\Lambda_j(Sub)$, $j \in \{i, e\}$. Panel C of the table reports present values of all deals in the market, $PV(All)$, and deals completed by quartiles of investor and entrepreneur qualities, $PV_j(Sub)$, $j \in \{i, e\}$, in units of $PV(All)$.

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	$\pi^*(All)$	$\frac{\pi_i^*(All)}{\pi^*(All)}$	$\frac{\pi_e^*(All)}{\pi^*(All)}$	$\frac{\pi^*(Sub)}{\pi^*(All)}$	$\frac{\pi_i^*(Sub)}{\pi^*(Sub)}$	$\frac{\pi_e^*(Sub)}{\pi^*(Sub)}$	$\frac{\pi^*(Sub)}{\pi^*(All)}$	$\frac{\pi_i^*(Sub)}{\pi^*(Sub)}$	$\frac{\pi_e^*(Sub)}{\pi^*(Sub)}$	$\frac{\pi^*(Sub)}{\pi^*(All)}$	$\frac{\pi_i^*(Sub)}{\pi^*(Sub)}$	$\frac{\pi_e^*(Sub)}{\pi^*(Sub)}$	$\frac{\pi^*(Sub)}{\pi^*(All)}$	$\frac{\pi_i^*(Sub)}{\pi^*(Sub)}$	$\frac{\pi_e^*(Sub)}{\pi^*(Sub)}$
j =investor	100	46.23	53.77	64.04	41.20	58.80	107.31	43.91	56.09	116.33	48.25	51.75	126.90	50.08	49.92
j=entrepreneur	100	46.23	53.77	0	–	–	3.69	50.24	49.76	34.05	48.96	51.04	105.85	46.15	53.85

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
Frequency of deals	$\Lambda_j(All)$	$\Lambda_j(Sub)$	$\Lambda_j(Sub)$	$\Lambda_j(Sub)$	$\Lambda_j(Sub)$
j =investor	1.320	1.540	1.237	1.237	1.237
j =entrepreneur	1.202	0	0.001	0.352	4.155

Panel C: Present values of deals

Subsample (Sub)	All deals (All)	0-25% j quantile	25-50% j quantile	50-75% j quantile	75-100% j quantile
Ratio of PV of deals	$\frac{PV_j(All)}{PV(All)}$	$\frac{PV_j(Sub)}{PV(All)}$	$\frac{PV_j(Sub)}{PV(All)}$	$\frac{PV_j(Sub)}{PV(All)}$	$\frac{PV_j(Sub)}{PV(All)}$
j =investor	73.01	11.63	19.19	16.02	26.17
j =entrepreneur	26.99	0	0.01	4.75	22.24

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 four counterfactuals, in which investors are restricted from including contractual features implemented via (a) participation preference, (b) pay-to-play, (c) the VC board seat, and (d) both participation preference and the VC board seat. Panel A of the table reports the change in the expected total value and split of value across all deals and deals completed by quartiles of investor and entrepreneur qualities. *Rebalanced terms only* rows report the partial effect from rebalancing the remaining contract terms such that the set of matches does not change, and *Equilibrium* rows report the entire effect from rebalancing and rematching in the new equilibrium. The change in expected total values across all deals and in quartile subsamples, $\Delta\pi^{cf}(All) = \pi^{cf}(All) - \pi^*(All)$ and $\Delta\pi^{cf}(Sub) = \pi^{cf}(Sub) - \pi^*(Sub)$, as well as 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 total value in the relevant subsample, $\pi^*(All)$ and $\pi^*(Sub)$ correspondingly. Panel B of the table reports the change in expected deal frequencies across all market participants, $\Delta\Lambda_j^{cf}(All) = \Lambda_j^{cf}(All) - \Lambda_j^*(All)$, 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 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 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	-0.17	-0.17	0	-0.10	-0.10	0	0	0	0	-0.18	-0.18	0	-0.34	-0.34	0
Equilibrium	1.19	-0.99	2.18	-3.01	-0.84	-2.17	3.63	-0.65	4.29	3.76	-0.19	3.96	3.65	-0.17	3.82
j =entrepreneur															
Rebalanced terms only	-0.17	-0.17	0	–	–	–	-0.29	-0.29	0	-0.27	-0.27	0	-0.17	-0.17	0
Equilibrium	1.19	-0.99	2.18	–	–	–	60.13	26.87	33.26	18.02	5.96	12.06	3.38	-0.03	3.41
No pay-to-play															
j =investor															
Rebalanced terms only	-0.03	-0.03	0	-0.13	-0.13	0	0	0	0	0	0	0	0	0	0
Equilibrium	-1.88	-0.48	-1.40	-6.00	-0.68	-5.32	0	0	0	0	0	0	0	0	0
j =entrepreneur															
Rebalanced terms only	-0.03	-0.03	0	–	–	–	0	0	0	0	0	0	-0.03	-0.03	0
Equilibrium	-1.88	-0.48	-1.40	–	–	–	54.00	27.13	26.87	13.52	6.32	7.21	0.37	0.55	-0.17
No VC board seat															
j =investor															
Rebalanced terms only	-0.03	-0.03	0	0	0	0	-0.04	-0.04	0	-0.09	-0.09	0	-0.01	-0.01	0
Equilibrium	0.94	0.17	0.78	-0.54	-0.14	-0.40	0.73	-0.14	0.87	0.73	-0.07	0.80	0.77	0	0.77
j =entrepreneur															
Rebalanced terms only	-0.03	-0.03	0	–	–	–	-0.01	-0.01	0	-0.01	-0.01	0	-0.03	-0.03	0
Equilibrium	0.94	0.17	0.78	–	–	–	1.10	0	1.10	1.08	-0.04	1.12	1.02	0.21	0.81
No PP and VC board seat															
j =investor															
Rebalanced terms only	-0.29	-0.29	0	-0.30	-0.30	0	-0.04	-0.04	0	-0.27	-0.27	0	-0.50	-0.50	0
Equilibrium	0.87	-1.65	2.52	-4.54	-1.93	-2.61	4.46	-0.84	5.3	4.52	-0.36	4.89	4.36	-0.36	4.72
j =entrepreneur															
Rebalanced terms only	-0.29	-0.29	0	–	–	–	-0.52	-0.52	0	-0.44	-0.44	0	-0.29	-0.29	0
Equilibrium	0.87	-1.65	2.52	–	–	–	127.56	58.18	69.39	15.74	4.36	11.38	4.12	-0.24	4.37

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	2.85	8.88	0	0	0
j =entrepreneur	2.85	–	287.08	49.46	-1.33
No pay-to-play					
j =investor	1.72	5.38	0	0	0
j =entrepreneur	1.72	–	287.08	49.46	-2.55
No VC board seat					
j =investor	-1.24	-3.87	0	0	0
j =entrepreneur	-1.24	–	0	0	-1.35
PP and VC board seat					
j =investor	4.33	13.53	0	0	0
j =entrepreneur	4.33	–	1050.67	66.38	-1.33

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	3.62	-0.83	-0.39	-0.29	-0.06	-0.09
j =entrepreneur	3.62	4.45	0	0.03	1.95	2.47
No pay-to-play						
j =investor	1.39	-0.08	-0.08	0	0	0
j =entrepreneur	1.39	1.47	0	0.03	1.44	0
No VC board seat						
j =investor	0.33	-0.15	-0.06	-0.06	-0.02	0
j =entrepreneur	0.33	0.48	0	0	0.10	0.38
No PP and VC board seat						
j =investor	4.73	-1.16	-0.48	-0.37	-0.12	-0.19
j =entrepreneur	4.73	5.89	0	0.14	2.86	2.88

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 investors 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	-2.13	5.05	0.89	1.24	1.10	1.82
j =entrepreneur	-2.13	-7.18	0.01	0.01	-3.46	-3.73
5X Frequencies of encounters						
j =investor	-1.74	10.55	1.90	2.52	2.29	3.84
j =entrepreneur	-1.74	-12.29	0.02	0.02	-4.22	-8.11
10X Frequencies of encounters						
j =investor	-1.75	14.46	2.73	3.57	3.06	5.11
j =entrepreneur	-1.75	-16.21	0.04	0.05	-4.64	-11.66

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. Panel C describes estimates of the model with exogenous time-varying VC capital constraints. Significance: Significance: ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$.

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