Skills and Bargaining Power in Venture Capital Markets

Shmuel Baruch, Hyun Joong Kim, Chris Yung*

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Abstract

The venture capital literature documents fluctuations in bargaining power. Market conditions sometimes favor entrepreneurs ("*money chasing deals*" accompanied by boom-bust cycles) and other times favor VCs. We derive the determinants of bargaining power as a function of i) public market valuations, ii) project characteristics, iii) distribution of skills in the economy, as measured by the extent to which it is difficult to imitate incumbent VC and entrepreneurs. We explore how these dynamics contribute to overinvestment (entry of low-quality entrepreneurs) or underinvestment (exit of high-quality entrepreneurs).

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*Baruch: University of Rome, Tor Vergata; shmuel.baruch@uniroma2.it. Kim: University of Southern Denmark; hyun@sam.sdu.dk. Yung: University of Virginia; cay2m@virginia.edu.

1 Introduction

The allocation of bargaining power between entrepreneurs and venture capitalists (VCs) potentially affects nearly every measure observed by empiricists. This includes i) the financial returns earned by VC partners, ii) the willingness of VC limited partners to provide capital, iii) tendency toward overinvestment (e.g., a *"money chasing deals"* environment and the resulting boom-bust cycles) or underinvestment, iv) the patience shown by VCs toward poorly performing projects, and v) the amount of innovation created within VC markets.

In this paper we identify the determinants of bargaining power. The approach in the theoretical literature has been to assign bargaining power either exogenously[1] or to divide it in a seemingly "fair" manner. One such division employs Nash bargaining.[2] Under that approach, economic surplus is split between the two parties so as to maximize the product of entrepreneurial surplus utility (taken to some power β) multiplied against VC surplus utility (taken to the power $1-\beta$). The parameter β serves as a proxy for bargaining power. The value of β is typically specfically exogenously, and therefore such models cannot identify the ultimate source of bargaining power.

Our approach is instead Walrasian. Suppose bargaining power is skewed towards entrepreneurs. In that case, few agents would want to become VCs whereas many agents would become entrepreneurs. Such an imbalance is untenable: if a large number of entrepreneurs vies for funding from a small number of VCs, then the forces of competition will push the contract terms to become more VC-friendly. Conversely, if the contract terms are too VC-friendly then the opposite imbalance holds.

[1] Papers with exogenous bargaining power include Fulghieri and Sevilir (2009), Jovanovic and Szentes (2013), and Baruch, Kim, and Yung (2024).

[2] Papers that employ Nash bargaining with a fixed β include Repullo and Suarez (2004), Fairchild (2014), Inderst and Müller (2004), Boadway et al. (2007), Casamatta and Haritchabalet (2007), Wang and Wang (2012), Hellmann and Thiele (2015), Guo, Lou, and Perez-Castrillo (2015), Opp (2019), Akcigit et al. (2022), and Ewens, Gorbenko, and Korteweg (2022).

We model free entry with heterogeneous agents on both sides of the market. We characterize equilibrium through a unique bargaining power parameter that equates supply with demand. The basic idea is as follows. A continuum of agents can choose to become VCs or entrepreneurs. Agents have heterogeneous aptitude in each occupation. After making occupational choices, entrepreneurs and VCs are randomly matched. Within each matched pair, the VC evaluates the entrepreneur's project and decides whether to provide funding. If funding occurs, the startup receives an idiosyncratic shock and then payoffs are distributed.

In equilibrium, high-ability candidates within each occupation choose to become active. There exists a marginal (worst active) VC and a marginal (worst active) entrepreneur. These marginal agents earn zero profits whereas inframarginal agents earn strictly positive profits. We show that economic rents are determined by the substitutability of one's skill set; i.e., agents tend to earn larger profits when there is a shortage of agents of similar quality, and when the market is 'hot' so that market clearing necessitates the participation of agents significantly worse than them.

More specifically, we model agent quality as frawn from a continuous distribution. We refer to an agent as 'special' if the probability density is low in the region adjacent to him; that is, there are few agents of comparable quality. One key parameter in our model is v, defined as the exit value of successful projects. When exit values increase, activity in the VC market also increases. The variable v, therefore, serves as a measure of market heat. A second key parameter in our model, $k \in (0,1)$, acts as a proxy for bargaining power. This parameter indicates the share of the equity stake allocated to the entrepreneur. Naturally, higher values of k attract more entrepreneurs and fewer VCs, so that there exists a unique k that equates supply and demand. We are interested in the sign of $\frac{\partial k}{\partial v}$ which indicates how bargaining power varies with market heat. In general this sign is ambiguous. However, our model has the following properties:

1. Hot markets favor the party who is more ‘special’ (i.e., the party whose skills are less easily replaced at the current equilibrium).

2. Hot markets favor the party whose payoffs are less sensitive to it at equilibrium.

3. (*“Rich get richer”*) Hot markets favor the side with more dispersion in quality. In turn, dispersion in quality implies that the high quality agents earn high profits. Further improvements in market conditions make these ’rich’ agents doubly better off: directly because exit values grow, and indirectly because financial contracts become more favorable.

To understand Property 1, imagine a technological shock that increases exit values; i.e., public markets pay a higher price for successful startup firms. Given higher exit values, more entrepreneurs are enticed to create startups. Consequently more VCs must be active to satisfy this capital demand. But suppose there is a large mass of entrepreneurs with skills approximately similar to the (previously) worst active entrepreneur. In such a case, entrepreneurs are not particularly ‘special’. If so, a small positive shock to investment opportunities could potentially induce a large influx of new entrepreneurs. But suppose by contrast that there is little or no mass just below the worst active VCs (i.e., active VCs are not easily substitutable). Without changes to bargaining power, such a positive shock would cause capital demand to exceed capital supply. To maintain equilibrium, bargaining power endogenously shifts toward the VC.

To understand property 2, consider a positive shock to net present values that affects VCs more than entrepreneurs. For example, suppose a shock reduces the expenses of both parties, but has a stronger effect on VC expenses (the relative price of inputs changes, or the set of opportunity costs changes). All else equal, this would incentivize relatively more VCs to enter the market. Bargaining power must endogenously shift from VCs to entrepreneurs to maintain market clearing.

Property 3 is similarly intuitive. For example, consider a scenario in which many entrepreneurs are approximately similarly quality, i.e., entrepreneurial ideas are easily substitutable, whereas VCs have significant dispersion in quality. In such a case, marginal VCs earn zero profit (by definition) whereas high-quality VCs earn high profits, and indeed are the only player in the game who does so. When exit values increase, the contract adjusts so that the new marginal agents all earn zero profit. Contracts terms cannot adjust in favor of entrepreneurs or else they would now earn strictly positive profits. Because contract terms adjust in VC favor, and exit values also increase, the high-quality VC earn much higher profits after this shock.

Finally, we solve a version of the model in which there is 'sticky' supply, i.e., no new VCs can enter the market. Our results illustrate an extreme case in which the rents disproportionately accrue to incumbents; bargaining power unambiguously shifts to incumbent VCs when market heat increases.

1.1 Related Literature

Inderst and Müller (2004) model a situation in which firm value depends upon effort provision by both the entrepreneur and VCs. Agents are matched in a costly search model and, once matched, they engage in Nash bargaining.

Nash bargaining requires specifying each party's reservation utility − what happens if the deal breaks down − as well as parameter β which captures the notion of bargaining power once the firm is created. Inderst and Müller (2004) employ Walrasian-like reasoning in determining reservation utilities: they argue that if there is a large number of VCs, then entrepreneurs should have higher reservation values because it is easier to find alternatives. The Nash bargaining itself uses an exogenous bargaining power parameter β. The central finding of Inderst and Müller (2004) is that imbalances in this parameter are harmful. Specifically, if one party holds too much power, then the other party contributes too little effort. In this manner, bargaining power imbalances destroy firm value.

Our assumptions and conclusions are quite different from Inderst and Müller (2004). In their model, entrepreneurs are identical. Throughout most of the paper, VCs are identical as well, although there is an extension allowing some VCs who are "portfolio investors" offering no value-added). Another extension admits an exogenous "entry cost" for VCs and requires that the net profits are zero. They examine the effect of changes in this entry cost. Our paper differs on all of these margins. Both entrepreneurs and VCs are heterogeneous, and there is free entry on both sides. In our model, almost all VCs – all but the marginal one – earn strictly positive economic profits, as their skills are imperfectly substitutable. Startups are operated inefficiently in Inderst and Müller (2004) but efficiently in our model.

Another related paper is Yung (2017) which also uses Walrasian reasoning. That paper posits heterogeneous agents on both the supply side and demand side, but it does not explore determinants of bargaining power. Instead, it focuses on identifying cross-sectional dispersion in agent skill. Yung (2017) shows empirically that high-quality VCs are more likely to be founded during cold markets, whereas hot markets induce the formation of lemon VC funds.

Potential conflicts over liquidation decisions are shared with Jovanovic and Szentes (2013). They argue that VCs are in short supply and have better outside options – they can always reallocate investment to another portfolio firm – and are therefore more impatient than entrepreneurs. Jovanovic and Szentes (2013) study the liquidation decisions of the VC, assuming that projects develop over time with a hump-shaped success probability.

Contrary to their approach, we allow free entry of VCs rather than assuming they are in short supply. In our model, profit-sharing rules are endogenously determined and depend on the characteristics of projects, as well as the distribution of skills across agents.

2 Model

2.1 Overview

This subsection briefly sketches out the players of the game and the timing of their actions. Subsequent sections solve the model, starting from the last stage and working backward.

In the economy, a population of potential entrepreneurs (of mass Ω_D) are endowed with private information about their ability to generate business ideas. On the other side of the economy, a group of potential VCs (with mass Ω_S) hold private information about their ability to screen business ideas.

Period	Actions
$T = 1$	Potential VCs and entrepreneurs privately observe their abilities.
$T = 2$	Each potential entrepreneur generates one idea of unknown quality w.
$T = 3$	Everyone decides whether to enter the venture market, considering their search costs.
$T = 4$	Nature matches entrant VCs and entrepreneurs.
$T = 5$	VC observes a signal correlated with w, and decides whether to provide funding.
$T = 6$	Funded projects begin life. Payoffs occur.

Table 1: The timeline of the model

Each agent in both groups privately observes this information and decides whether to enter the VC market. Once an entrepreneur (he) and a VC (she) enter the VC market, they are randomly matched. During the match, the VC evaluates the business idea, receives a signal, and decides whether to fund it. The model's timeline, along with a preview of key variables, is as in the above table.

2.1.1 Entrepreneurs, Business Ideas and VCs

At $T = 1$, each potential entrepreneur i costlessly generates one idea associated with a random variable w corresponding to the idea's quality. In particular, $w_i \in \{w_B, w_G\}$, where w_G is considered as the quality level that may lead to a positive outcome, while w_B is considered as a failure once it is revealed. The entrepreneur does not observe his w_i but instead knows only his likelihood of generating good ideas, denoted $p_i := \Pr(w_i = w_G)$. The variable p_i is an *iid* random variable that follows a known prior distribution, $G : (0, 1) \to [0, 1]$.

VCs cannot generate their own ideas, but are born with the ability to to evaluate the ideas of others. Whenever VC j is presented with an idea of entrepreneur i during their matching in the market, she receives a noisy signal of its quality. This signal takes the value $s_{i,j} \in \{H, L\}$. Let $\epsilon_{i,j} \in \{0, 1\}$ be an indicator representing whether this signal matches the actual quality w_i (e.g., when $w_i = w_G$ and $s_{i,j} = H$, then the signal is accurate with $\epsilon_{i,j} = 0$). The accuracy of the VC's signal follows:

$$\begin{aligned} \Pr(\epsilon_{i,j} = 1 \mid w_i, p_i, e_j) &= e_j \\ \Pr(\epsilon_{i,j} = 0 \mid w_i, p_i, e_j) &= 1 - e_j \end{aligned} \tag{1}$$

The variable e_j is an *iid* random variable following a known prior discrete distribution $F : (0, 1/2) \to [0, 1]$. We further assume

$$\begin{aligned} \Pr(w_i = w_G \mid p_i, e_j) &= p_i \\ \Pr(w_i = w_B \mid p_i, e_j) &= 1 - p_i \end{aligned} \tag{2}$$

Potential entrepreneurs in our model have one single decision: they decide whether to pay the search cost D to enter the market and be matched with a VC. These costs can be equivalently viewed as an opportunity cost of time. For example, when preparing a proposal to a VC, an entrepreneur might build a prototype, gather scientific or market data, spend time polishing the "pitch", etc.

Potential VCs in our model have two decisions. First, they decide whether to pay the search cost A to enter the market and be matched with an entrepreneur. Second, upon observing $s_{i,j}$, they decide whether to fund the project or not.

2.1.2 Firm Payoffs ($T = 6$)

If VC funds the project with the early-stage seed investment $I > 0$, Nature then selects either $w_i = w_G$ or $w_i = w_B$ according to (2). This value is then privately observed by the entrepreneur, who decides how to react. The entrepreneur can either immediately choose to liquidate, in which case both parties earn zero profits, or can "continue" in which case each party has a value function which incorporates the expected payoffs conditional on continuation. These value functions also incorporate (for example) any operating or effort costs required by either party conditional on continuation.[3] We assume these functions $\mathbf{V}^{vc}(w, k, v)$ and $\mathbf{V}^{e}(w, k, v)$ satisfy:

$$\begin{aligned} \mathbf{V}^{vc}(w_B, k, v) &< 0 \\ \mathbf{V}^{e}(w_B, k, v) &< 0 \\ \mathbf{V}^{vc}(w_G, k, v) &> 0 \\ \mathbf{V}^{e}(w_G, k, v) &> 0 \end{aligned} \tag{3}$$

[3] In the appendix, we give an example with a specific functional form with costly effort by each party and convex effort costs.

and the following partial derivatives

$$\begin{aligned}\frac{\partial \mathbf{V}^{vc}}{\partial v} > 0 \\ \frac{\partial \mathbf{V}^{e}}{\partial v} > 0 \\ \frac{\partial \mathbf{V}^{vc}}{\partial k} < 0 \\ \frac{\partial \mathbf{V}^{e}}{\partial k} > 0\end{aligned} \tag{4}$$

Equation (3) ensures that the entrepreneur and VC agree on liquidation decisions. Equation (4) ensures that v acts in a manner consistent with our interpretation of it as an exit value. For a given k, higher exit values for completed firms give a higher payoff to both parties. We specify the sign only of this partial derivative rather than the specific functional form to allow for generality. For example, each party may pay a different fraction of the ongoing operating expenses needed to bring the startup to maturity, or each party may enjoy differential reputational benefits of a successful completion. These effects need not be linear in v for example.

Equation (4) also ensures that k acts in a manner consistent with our interpretation of it the division of exit value between the VC and entrepreneur. Higher k is interpreted as giving the entrepreneur a larger ownership stake; therefore, it leads to a higher value to the entrepreneur.

2.1.3 The Investment Decision ($T = 5$) and Entry Decision ($T = 3$)

At $T = 4$, VCs that choose to search for a match get randomly assigned to one entrepreneur. Everyone is short-lived; their lifespan consists of one match only. We assume (for now and later verify) that entrepreneurs enter only if $p_i \geq p_{min}$ for some endogenous cutoff $p_{min} \in (0, 1)$, and the VC enters the market only if $e_j \leq e_{max}$ for another cutoff $e_{max} \in (0, 1)$.

Denoting the following conditional probabilities

$$\Pi' = \Pr(w_i = w_G \mid s_{i,j} = H,\ e_j,\ p_i \geq p_{min})$$

$$\Pi'' = \Pr(w_i = w_G \mid s_{i,j} = L,\ e_j,\ p_i \geq p_{min})$$

$$\Pi''' = \Pr(s_{i,j} = H \mid e_j,\ p_i \geq p_{min})$$

$$\Pi'''' = \Pr(s_{i,j} = H,\ w_i = w_G \mid p_i,\ e_j \leq e_{max})$$

we impose and verify four conditions:

1) Upon observing the high signal, the VC chooses to invest.

$$\underbrace{\Pi' \left\{\mathbf{V}^{vc}\left(w_G, k, v\right) - I\right\} + (1 - \Pi')(-I)}_{IC_H} \geq 0 \tag{5}$$

2) Upon observing the low signal, the VC chooses not to invest.

$$\underbrace{\Pi'' \left\{\mathbf{V}^{vc}\left(w_G, k, v\right) - I\right\} + (1 - \Pi'')(-I)}_{IC_L} < 0 \tag{6}$$

3) For entrant VCs, the expected payoff from search is non-negative.

$$\Pi''' \times IC_H + (1 - \Pi''') \times 0 - A \geq 0 \tag{7}$$

4) For entrant entrepreneurs, the expected payoff from search is non-negative.

$$\Pi'''' \times \mathbf{V}^{e}\left(w_G, k, v\right) + (1 - \Pi'''') \times 0 - D \geq 0 \tag{8}$$

Because $\Pi''' \leq 1$ and $A > 0$, Conditions (7) and (6) together imply (5). Therefore (5) never binds. The intuition is that if the VC earns non-negative profit from the game overall, then she must also earn non-negative profit conditional on investing after seeing a high signal.

2.2 Market Equilibrium and Model Properties

Following from the entry conditions in the previous subsection combined with the market-clearing condition, we see that market equilibrium is described by a set of three equations. Here, the entry conditions are of marginal-quality players who are barely allowed to enter the market; therefore, they comprise the VC supply and demand in the VC market.

Proposition 2.1 (Entry Decisions)**.** *If the triple $\{p_{min}, e_{max}, k\}$ is part of a Bayesian Nash equilibrium, it must satisfy the following system of equations:*

$$J := \mathbf{V}^{e}\left(w_G, k, v\right) p_{min}\left[1 - \mathbb{E}\left(e|\, e_{max}\right)\right] - D = 0 \tag{9}$$

$$L := \left[\mathbf{V}^{vc}\left(w_G, k, v\right) - I\right] \mathbb{E}\left(p|\, p_{min}\right)\left(1 - e_{max}\right) - I\left[1 - \mathbb{E}\left(p|\, p_{min}\right)\right] e_{max} - A = 0 \tag{10}$$

$$H := F\left(e_{max}\right) - \omega\left[1 - G\left(p_{min}\right)\right] = 0 \tag{11}$$

subject to (the incentive compatibility condition (6))

$$\left[\mathbf{V}^{vc}\left(w_G, k, v\right) - I\right] \mathbb{E}\left(p|\, p_{min}\right) e_{max} - I\left[1 - \mathbb{E}\left(p|\, p_{min}\right)\right]\left(1 - e_{max}\right) \leq 0 \tag{12}$$

where

$$\mathbb{E}(e|e_{max}) := \mathbb{E}\left(e_j|\, e_j \leq e_{max}\right) = \frac{1}{F\left(e_{max}\right)} \int_0^{e_{max}} edF(e)$$

$$\mathbb{E}\left(p|\, p_{min}\right) := \mathbb{E}\left(p_i|\, p_i \geq p_{min}\right) = \frac{1}{1 - G\left(p_{min}\right)} \int_{p_{min}}^{1} pdG\left(p\right)$$

and $\omega := \Omega_S/\Omega_D$ is the proportion of the VC population (Ω_S) to the entrepreneur population (Ω_D).

Proof: See Appendix.

The intuition of Proposition 2.1 is as follows. Equation (9) represents the entry condition of the marginal entrepreneur, and is constructed by rewriting equation (8). The entrepreneur's utility is increasing in his own quality p_i, and there exists a cutoff p_{min} such that the entrepreneur is indifferent to entry.

Equation (10) is the entry condition of the marginal VC, and is constructed by rewriting equation (7). The VC's utility is decreasing in e_j. There exists a cutoff e_{max} such that the VC is indifferent to entry.

Condition (11) requires that supply equals demand (the market-clearing condition). In equilibrium, k must induce a balance between the number of VCs and entrepreneurs. (Note the dependence of k in equations (9) and (10), so that k affects e_{max} and p_{min}). Counterfactually, if k were too large, there would be an imbalance in which too many entrepreneurs seek funding from too few VCs (i.e., $F(e_{max}) < \omega [1 - G(p_{min})]$). If k were too small, the opposite imbalance holds.

Finally, note that satisfaction of $\{(9), (10), (11)\}$ is necessary for an equilibrium but not sufficient. In particular there may be $\{p_{min}, e_{max}, k\}$ which satisfy this system but not condition (6)[4]. In the numerical examples that follow, we solve the system of equations and then verify that (6) holds.

Any equilibrium $\{p_{min}, e_{max}, k\}$ must satisfy the system in Proposition 2.1. It is not possible to explicitly solve this system in general, but in what follows we examine comparative static properties using the implicit function theorem.

[4]Failure of (6) implies that the VC wants to fund all projects regardless of the signal received. In such cases (when all projects are positive NPV) then we would not need a market for venture capital.

For example, consider varying the the exit payoff v. This parameter can be considered a proxy for hot markets. Totally differentiating this system with respect to v, we have

$$\frac{dJ}{dv} = \underbrace{\frac{\partial J}{\partial v}}_{\oplus} + \underbrace{\frac{\partial J}{\partial p_{min}}}_{\oplus} \times \frac{\partial p_{min}}{\partial v} + \underbrace{\frac{\partial J}{\partial e_{max}}}_{\ominus} \times \frac{\partial e_{max}}{\partial v} + \underbrace{\frac{\partial J}{\partial k}}_{\oplus} \times \frac{\partial k}{\partial v} = 0$$

$$\frac{dL}{dv} = \underbrace{\frac{\partial L}{\partial v}}_{\oplus} + \underbrace{\frac{\partial L}{\partial p_{min}}}_{\oplus} \times \frac{\partial p_{min}}{\partial v} + \underbrace{\frac{\partial L}{\partial e_{max}}}_{\ominus} \times \frac{\partial e_{max}}{\partial v} + \underbrace{\frac{\partial L}{\partial k}}_{\ominus} \times \frac{\partial k}{\partial v} = 0$$

$$\frac{dH}{dv} = \underbrace{\frac{\partial H}{\partial p_{min}}}_{\oplus} \times \frac{\partial p_{min}}{\partial v} + \underbrace{\frac{\partial H}{\partial e_{max}}}_{\oplus} \times \frac{\partial e_{max}}{\partial v} = 0$$

The above is a three-equation system which we solve for the three unknowns $\left\{\frac{\partial p_{min}}{\partial v}, \frac{\partial e_{max}}{\partial v}, \frac{\partial k}{\partial v}\right\}$.

After omitted algebra, the solution is:

$$\begin{aligned}\frac{\partial e_{max}}{\partial v} &= \frac{\frac{\partial H}{\partial p_{min}}\left(\frac{\partial J}{\partial k} \times \frac{\partial L}{\partial v} - \frac{\partial L}{\partial k} \times \frac{\partial J}{\partial v}\right)}{\frac{\partial J}{\partial k} \times \frac{\partial H}{\partial e_{max}} \times \frac{\partial L}{\partial p_{min}} - \frac{\partial J}{\partial k} \times \frac{\partial L}{\partial e_{max}} \times \frac{\partial H}{\partial p_{min}} - \frac{\partial H}{\partial e_{max}} \times \frac{\partial L}{\partial k} \times \frac{\partial J}{\partial p_{min}} + \frac{\partial L}{\partial k} \times \frac{\partial J}{\partial e_{max}} \times \frac{\partial H}{\partial p_{min}}} \\ &= \frac{\oplus\left(\oplus \oplus - \ominus \oplus\right)}{\oplus} = \frac{\oplus}{\oplus} > 0\end{aligned}$$

$$\begin{aligned}\frac{\partial p_{min}}{\partial v} &= -\frac{\frac{\partial H}{\partial e_{max}}\left(\frac{\partial J}{\partial k} \times \frac{\partial L}{\partial v} - \frac{\partial L}{\partial k} \times \frac{\partial J}{\partial v}\right)}{\frac{\partial J}{\partial k} \times \frac{\partial H}{\partial e_{max}} \times \frac{\partial L}{\partial p_{min}} - \frac{\partial J}{\partial k} \times \frac{\partial L}{\partial e_{max}} \times \frac{\partial H}{\partial p_{min}} - \frac{\partial H}{\partial e_{max}} \times \frac{\partial L}{\partial k} \times \frac{\partial J}{\partial p_{min}} + \frac{\partial L}{\partial k} \times \frac{\partial J}{\partial e_{max}} \times \frac{\partial H}{\partial p_{min}}} \\ &= -\frac{\oplus\left(\oplus \oplus - \ominus \oplus\right)}{\oplus} < 0\end{aligned}$$

$$\begin{aligned}\frac{\partial k}{\partial v} &= \frac{\frac{\partial H}{\partial e_{max}} \times \frac{\partial L}{\partial v} \times \frac{\partial J}{\partial p_{min}} - \frac{\partial J}{\partial e_{max}} \times \frac{\partial L}{\partial v} \times \frac{\partial H}{\partial p_{min}} - \frac{\partial H}{\partial e_{max}} \times \frac{\partial L}{\partial p_{min}} \times \frac{\partial J}{\partial v} + \frac{\partial J}{\partial v} \times \frac{\partial L}{\partial e_{max}} \times \frac{\partial H}{\partial p_{min}}}{\frac{\partial J}{\partial k} \times \frac{\partial H}{\partial e_{max}} \times \frac{\partial L}{\partial p_{min}} - \frac{\partial J}{\partial k} \times \frac{\partial L}{\partial e_{max}} \times \frac{\partial H}{\partial p_{min}} - \frac{\partial H}{\partial e_{max}} \times \frac{\partial L}{\partial k} \times \frac{\partial J}{\partial p_{min}} + \frac{\partial L}{\partial k} \times \frac{\partial J}{\partial e_{max}} \times \frac{\partial H}{\partial p_{min}}} \\ &= \frac{\oplus \oplus \oplus - \ominus \ominus \oplus - \oplus \ominus \oplus + \oplus \ominus \oplus}{\oplus}\end{aligned}$$

The partial derivatives indicate the key properties of our model. The result $\frac{\partial p_{min}}{\partial v} < 0$ and

$\frac{\partial e_{max}}{\partial v} > 0$ are intuitively obvious. During hot markets, we expect that more entrepreneurs are active. Increased demand necessitates that more VCs must also be active, because markets clear.

In contrast, $\frac{\partial k}{\partial v}$ is of an indeterminant sign. Rearranging slightly, we show that $\frac{\partial \kappa}{\partial v}$ is proportional to

$$f\left(e_{max}\right)\left[\underbrace{\frac{\partial L}{\partial v}\times\frac{\partial J}{\partial p_{min}}}_{\text{Direct Effect } 1>0}-\underbrace{\frac{\partial J}{\partial v}\times\frac{\partial L}{\partial p_{min}}}_{\text{Indirect Effect } 1>0}\right]+\omega g\left(p_{min}\right)\left[\underbrace{\frac{\partial J}{\partial v}\times\frac{\partial L}{\partial e_{max}}}_{\text{Direct Effect } 2<0}-\underbrace{\frac{\partial J}{\partial e_{max}}\times\frac{\partial L}{\partial v}}_{\text{Indirect Effect } 2<0}\right] \quad (13)$$

This expression (13) indicates that comparative static properties with respect to v depend on a set of direct and indirect forces which push in opposing directions. Those terms multiplied by $f\left(e_{max}\right)$ capture the effects of v on capital supply (i.e., the number of VCs). The term $\frac{\partial L}{\partial v}$ represents the direct effect of changes in v to VC payoffs. Higher exit payoffs to the VC imply that more VCs enter. The next term in the expression $\frac{\partial L}{\partial p_{min}}$ captures an indirect effect: specifically, a change in v affects the pool of entrepreneurs willing to seek funding, in turn altering the VC's payoffs indirectly. Those terms contained in the first bracket contain the net change in capital supply, considering both direct and indirect effect.

Similarly, the terms in the second bracket indicate the effect of v on capital demand. This includes a direct force (higher v resulting in higher payoffs to entrepreneurs), as well as an indirect force (higher v alters the pool of VCs that the entrepreneur encounters).

Theorem 2.2 (Comparative statics related to costs)**.** *If a solution* $\{p_{min}, e_{max}, k\}$ *exists, it is unique. Moreover, equilibrium has the following properties:*

1. $\frac{\partial e_{max}}{\partial A} < 0$, $\frac{\partial p_{min}}{\partial A} > 0$, $\frac{\partial k}{\partial A} < 0$

2. $\frac{\partial e_{max}}{\partial D} < 0$, $\frac{\partial p_{min}}{\partial D} > 0$, $\frac{\partial k}{\partial D} > 0$

3. $\frac{\partial e_{max}}{\partial I} < 0$, $\frac{\partial p_{min}}{\partial I} > 0$, $\frac{\partial k}{\partial I} < 0$

The signs are all intuitive. For example, increasing the costs borne by the VC tends to decrease the number of active VCs, and therefore also decreases the number of active entrepreneurs. This change endogenously shifts bargaining power towards VCs, enabling them to recoup these increased costs. Altering entrepreneurial costs has the opposite effect.

To see that the solution is unique in k, we totally differentiate H:

$$\frac{dH}{dk} = \underbrace{\frac{\partial H}{\partial k}}_{=0} + \underbrace{\frac{\partial H}{\partial p_{min}}}_{\oplus} \times \underbrace{\frac{\partial p_{min}}{\partial k}}_{\ominus} + \underbrace{\frac{\partial H}{\partial e_{max}}}_{\oplus} \times \underbrace{\frac{\partial e_{max}}{\partial k}}_{\ominus} < 0$$

Because this derivative is negative, H has a unique level of k for which $H = 0$ holds. Heuristically, suppose a particular value k^* is associated with equilibrium. Increasing k strictly increases capital demand and strictly decreases capital supply, in which case markets no longer clear.

Theorem 2.3. *(Comparative statics related to the exit value)*

1. $\frac{\partial e_{max}}{\partial v} > 0$, $\frac{\partial p_{min}}{\partial v} < 0$

2. *If* $f\left(e_{max}\right)$ *is sufficiently large (small) relative to* $g\left(p_{min}\right)$, *then* $\frac{\partial k}{\partial v} > (<)\, 0$ *holds.*

3. *If* $\mathbf{V}^{e}$ *is sufficiently large (small) relative to* $\mathbf{V}^{vc} - I$, *then* $\frac{\partial k}{\partial v} > (<)\, 0$ *holds.*

4. *If* $\frac{\partial \mathbf{V}^{vc}}{\partial v}$ *is sufficiently large (small) relative to* $\frac{\partial \mathbf{V}^{e}}{\partial v}$, *then* $\frac{\partial k}{\partial v} > (<)\, 0$ *holds.*

Theorem 2.3.1 is intuitive. Increasing the net present value of projects implies that more projects will be funded. We observe an increase in both quantities supplied and demanded.

Theorem 2.3.2 is a main result (property 1 in Introduction). Without loss of generality, consider the case where $f\left(e_{max}\right)$ is large relative $g\left(p_{min}\right)$. In this case, a small change in e_{max} leads to a large change in the mass of active VCs. Hence, to clear the market, k must adjust upwards to temper the effect, giving more benefits to the entrepreneur (capital demand) side.

To see why Theorem 2.3.2 holds, we revisit the decomposition (13)

$$\frac{\partial k}{\partial v} \propto f\left(e_{max}\right)\left[\underbrace{\frac{\partial L}{\partial v} \times \frac{\partial J}{\partial p_{min}}}_{\text{Direct Effect 1>0}} - \underbrace{\frac{\partial J}{\partial v} \times \frac{\partial L}{\partial p_{min}}}_{\text{Indirect Effect 1>0}}\right] + \omega g\left(p_{min}\right)\left[\underbrace{\frac{\partial J}{\partial v} \times \frac{\partial L}{\partial e_{max}}}_{\text{Direct Effect 2<0}} - \underbrace{\frac{\partial J}{\partial e_{max}} \times \frac{\partial L}{\partial v}}_{\text{Indirect Effect 2<0}}\right]$$

Replacing these partial derivatives with their corresponding signs, we have

$$f(e_{max})\left[\underbrace{\oplus \times \oplus}_{\text{Direct Effect 1}} - \underbrace{\oplus \times \oplus}_{\text{Indirect Effect 1}}\right] + \omega g(p_{min})\left[\underbrace{\oplus \times \ominus}_{\text{Direct Effect 2}} - \underbrace{\ominus \times \oplus}_{\text{Indirect Effect 2}}\right]$$

Suppose $g(p_{min})$ is very small. In this case, the second bracketed term is irrelevant. In addition, when $g(p_{min})$ is small, the indirect direct in the first bracketed term is negligible. This holds because for a given change in entrepreneurial cutoff, the conditional expectation of entrepreneurial quality has little change since not much mass is added, making $\frac{\partial L}{\partial p_{min}} \approx 0$.

Together, these two facts imply that when $g(p_{min})$ is small the comparative static $\frac{\partial k}{\partial v}$ is governed mainly by Direct Effect 1, inducing $\frac{\partial k}{\partial v} > 0$. Intuitively, a (local) dearth of available entrepreneurs implies that contracting terms must shift towards them in order to increase VC activity.

Theorem 2.3.3 is a "*rich get richer*" effect described in property 3. To see why it holds mathematically, we rearrange (13) as follows:

$$\frac{\partial k}{\partial v} \propto \underbrace{\frac{\partial L}{\partial v}}_{>0} \cdot \left[f\left(e_{max}\right) \cdot \underbrace{\frac{\partial J}{\partial p_{min}}}_{>0} - \omega g\left(p_{min}\right) \cdot \underbrace{\frac{\partial J}{\partial e_{max}}}_{<0} \right] - \underbrace{\frac{\partial J}{\partial v}}_{>0} \cdot \left[f\left(e_{max}\right) \cdot \underbrace{\frac{\partial L}{\partial p_{min}}}_{>0} - \omega g\left(p_{min}\right) \cdot \underbrace{\frac{\partial L}{\partial e_{max}}}_{<0} \right]$$

By computing the partial derivative terms in the equation, its right-hand side is rewritten as

$$f\left(e_{max}\right) \cdot \frac{\partial \mathbf{V}^{vc}}{\partial v} \cdot \mathbf{V}^{e} \cdot \mathbb{E}\left(p \middle| p_{min}\right)\left(1 - e_{max}\right) \left\{ \left[1 - \mathbb{E}\left(e \middle| e_{max}\right)\right] + \omega g\left(p_{min}\right) \cdot p_{min} \cdot \frac{e_{max} - \mathbb{E}\left(e \middle| e_{max}\right)}{F\left(e_{max}\right)} \right\}$$
$$-g\left(p_{min}\right) \cdot \frac{\partial \mathbf{V}^{e}}{\partial v} \cdot \left[1 - \mathbb{E}\left(e \middle| e_{max}\right)\right] p_{min} \left\{ \begin{array}{c} f\left(e_{max}\right)\left\{\left(\mathbf{V}^{vc} - I\right)\left(1 - e_{max}\right) + I \cdot e_{max}\right\} \cdot \frac{\mathbb{E}\left(p | p_{min}\right) - p_{min}}{1 - G\left(p_{min}\right)} \\ \\ +\omega\left\{\left(\mathbf{V}^{vc} - I\right)\mathbb{E}\left(p \middle| p_{min}\right) - I\left[1 - \mathbb{E}\left(p \middle| p_{min}\right)\right]\right\} \end{array} \right\}$$

Suppose $\mathbf{V}^{vc} - I$ is small relative to $\mathbf{V}^{e}$. In the equation above, the second term dominates the first term, thereby making the sign of $\frac{\partial k}{\partial v}$ negative. At the same time, this implies a higher payoff dispersion on the VC than on the entrepreneurial side: high quality VC earn high rents, whereas the marginal VC − who has a noisier signal − makes more mistakes and earns zero profits. This dispersion is amplified during hot markets due to an increased influx of new marginal VCs, more severely on the VC side than the entrepreneur side. Hence, a newly adjusted contract term should be more VC-friendly in equilibrium to compensate for an increased payoff dispersion.

Such a consequence implies that high-quality VCs benefit doubly during hot markets; first, directly from increased exit payoffs and, secondly, from more favorable contract terms in a new equilibrium. Hence we name this phenomenon the "*rich get richer*" effect.

Theorem 2.3.4 implies that hot markets favor the side whose payoffs are less sensitive to it at equilibrium (property 2 in Introduction). As in Theorem 2.3.3, we find its mathematical rationale from the rearranged decomposition above; when $\frac{\partial \mathbf{V}^{vc}}{\partial v}$ is substantially large while $\frac{\partial \mathbf{V}^{e}}{\partial v}$ is small, the first term dominates over the second term, thereby determining the sign of $\frac{\partial k}{\partial v}$ to be positive.

Such a difference in degrees of sensitivity to market shocks implies disproportionate reactions of the value functions to such a change. In general, the payoffs are not necessarily proportional to the bargaining power allocation, especially when the division of operating costs for running a funded project between its entities does not equal it. For instance, when the entrepreneur burdens the division of cost higher than his assigned bargaining power k, we may say the division is 'imbalanced,' causing a disproportionate value function structure between the two entities. In such a case, the value functions would react disproportionately to a change in v. Moreover, if their ultimate division of exit payoffs upon the project's completion is not necessarily equal to the bargaining power allocation[5], we may observe a more severe difference between their degrees of sensitivity.

Next, we analyze how a change in the proportion of entrepreneur and VC side population affects the market equilibrium.

Theorem 2.4. *(Comparative statics related to population)*

1. $\frac{\partial p_{min}}{\partial \omega} > 0$, $\frac{\partial e_{max}}{\partial \omega} > 0$, $\frac{\partial k}{\partial \omega} < 0$

To understand the first and the second properties, note that as ω increases, entrepreneurs

[5] For instance, Baruch, Kim, and Yung (2024) show how the initial bargaining power (or equivalently, the equity allocation) varies over time in a dynamic setup that allows renegotiations between an entrepreneur and a VC whenever each of them needs to incentivize another.

become more numerous. Consequently, in equilibrium one does not need to dig as deeply into the pool of entrepreneurs. Thus p_{min} rises. For symmetric reasons, e_{max} rises. The third property has obvious intuition. As entrepreneurs become numerous relative to VCs, bargaining power shifts away from them.

3 Numerical examples and extensions

In this section, we develop an extended example illustrating the behavior of the model. For the purposes of the numerical example, we use the value functions developed in Baruch, Kim, and Yung (2024). In that model, once a startup firm begins operating, it develops in continuous time and reaches success or failure at some random stopping time. Before this termination, the firm requires a continuous operating expense c per unit of time to be paid. It is assumed that these costs are shared by the entrepreneur and VC, such that γc is paid by the entrepreneur where $(1-\gamma)c$ is paid by the VC.

Given an exogenous equity allocation $k \in (0,1)$ and $w \equiv w_G$, the value functions derived in that paper are as follows:

$$\mathbf{V}^e(w,k,v) = \begin{cases} PV(w,\gamma c,kv) & k<\gamma \\ \gamma PV(w,c,v) & k=\gamma \\ PV(w,c,v) - PV(w,(1-\gamma)c,(1-k)v) & k>\gamma \end{cases}$$

$$\mathbf{V}^{vc}(w,k,v) = \begin{cases} PV(w,c,v) - PV(w,\gamma c,kv) & k<\gamma \\ (1-\gamma)PV(w,c,v) & k=\gamma \\ PV(w,(1-\gamma)c,(1-k)v) & k>\gamma \end{cases}$$

where $PV(w,c,v)$, the total firm value of a VC-backed project, is the solution of the following optimal stopping problem:

$$PV(w,c,v) := \max_{T\in\mathcal{T}} E\left[1_{\{\tau<T\}}e^{-r\tau}v - \int_0^{\tau\wedge T} e^{-rt}c\,dt\right]$$
$$= c\times\max_{T\in\mathcal{T}} E\left[1_{\{\tau<T\}}e^{-r\tau}\frac{v}{c} - \int_0^{\tau\wedge T} e^{-rt}\,dt\right]$$
$$= c\times u\left(\max\{0, u^{-1}(v/c)-w\}\right) \quad (14)$$

and $u(\cdot)$ is the solution of the following initial value problem

$$\begin{cases} 1 = -\mu u' + \frac{1}{2}\sigma^2 u'' - ru, \\ u(0) = 0 \\ u'(0) = 0 \end{cases} \quad (15)$$

When we impose $r=\mu=0$, the total firm value and the stopping threshold (i.e., the level of W_t at which the entities agree to terminate the project) are

$$PV(w,c,v) = \frac{\left(-w\sqrt{c}+\sigma\sqrt{v}\right)^2}{\sigma^2}, \quad u^{-1}\left(\frac{v}{c}\right) = \sigma\sqrt{\frac{v}{c}}$$

and we have the closed-form solutions for the value functions under different ranges of k as follows:

1. When $k<\gamma$

$$\mathbf{V}^e(w,k,v) = \frac{\left(-w\sqrt{\gamma c}+\sigma\sqrt{kv}\right)^2}{\sigma^2}$$
$$\mathbf{V}^{vc}(w,k,v) = \frac{1}{\sigma^2}\left[\left(-w\sqrt{c}+\sigma\sqrt{v}\right)^2 - \left(-w\sqrt{\gamma c}+\sigma\sqrt{kv}\right)^2\right]$$

2. When $k = \gamma$

$$\mathbf{V}^e(w,k,v) = \frac{\gamma\left(-w\sqrt{c}+\sigma\sqrt{v}\right)^2}{\sigma^2}$$

$$\mathbf{V}^{vc}(w,k,v) = \frac{(1-\gamma)\left(-w\sqrt{c}+\sigma\sqrt{v}\right)^2}{\sigma^2}$$

3. When $k > \gamma$

$$\mathbf{V}^e(w,k,v) = \frac{1}{\sigma^2}\left[\left(-w\sqrt{c}+\sigma\sqrt{v}\right)^2 - \left(-w\sqrt{(1-\gamma)\,c}+\sigma\sqrt{(1-k)\,v}\right)^2\right]$$

$$\mathbf{V}^{vc}(w,k,v) = \frac{\left(-w\sqrt{(1-\gamma)\,c}+\sigma\sqrt{(1-k)\,v}\right)^2}{\sigma^2}$$

It is immediate to see that these functions are continuous in k and satisfy the partial derivative properties assumed in (4). Furthermore, for appropriate chosen $w \in \{w_B, w_G\}$, they also satisfy (3).

For this example, we assume that the VC quality e follows a uniform distribution on (0, $\frac{1}{2}$), while the entrepreneur quality p follows Beta(α=2, β=8). Such a distribution features an extremely thin right tail, so that entrepreneurs are in very short supply near p=1. For the rest of the analyses, we assign the parameter values as $w = 1.0$, $\mu = 0$, $\sigma = 0.5$, $\gamma = 0.5$, $\omega = 1.5$, $A = D = 25$, $I = 200$, $c = 1$ and $v \in (450, 700)$.

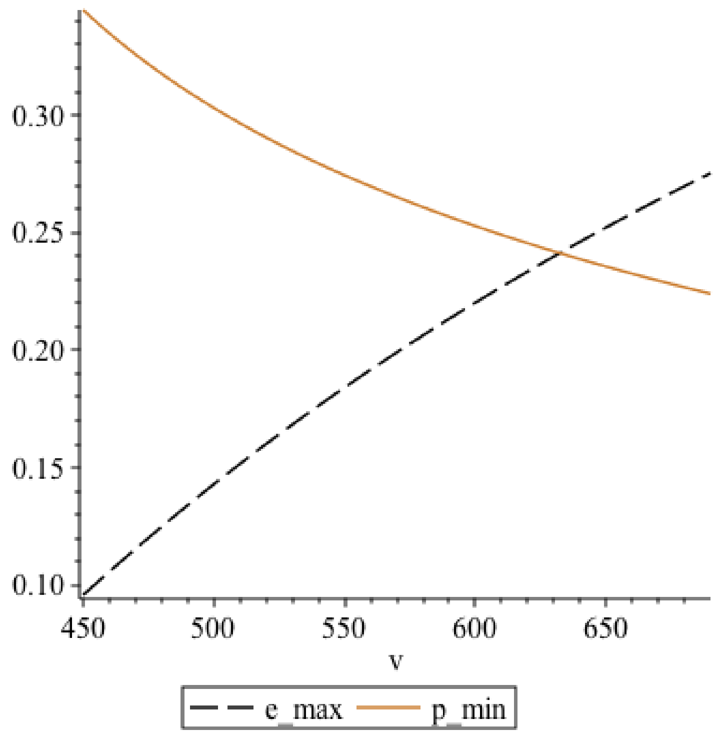

Figure 1: e_{max} and p_{min} as functions of v

Figure 1 shows the level of e_{max} and p_{min} consistent with equilibrium for each v. Consistent with Theorem 2.2.1, p_{min} is a declining function where e_{max} is an increasing function. That is, hot markets draw in agents on both sides of the market by relaxing the cutoffs for potential entrants.

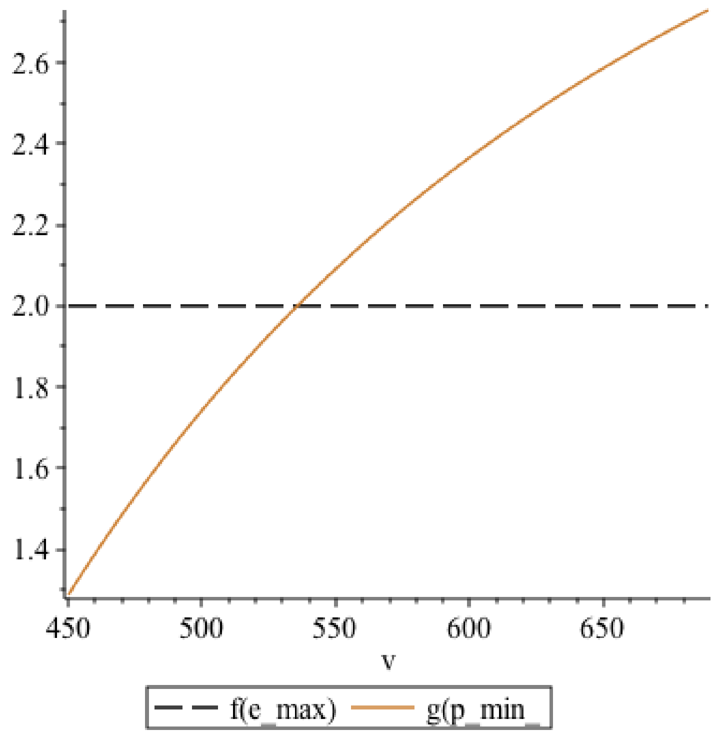

Figure 2: $f(e_{max})$ and $g(p_{min})$ as functions of v

Figure 2 illustrates the density associated with the marginal agent on each side of the market. Note when v=450, the density for the marginal entrepreneur is very low; entrepreneurs are locally scarce. This is because the market is cold and the overall NPV of projects is low. Consequently, only the right tail of entrepreneurs is active, and this tail is thin. As the market heats up, we move into a thicker part of the distribution.

This transition toward the thicker part of the entrepreneurial distribution is also evident in the bargaining power.

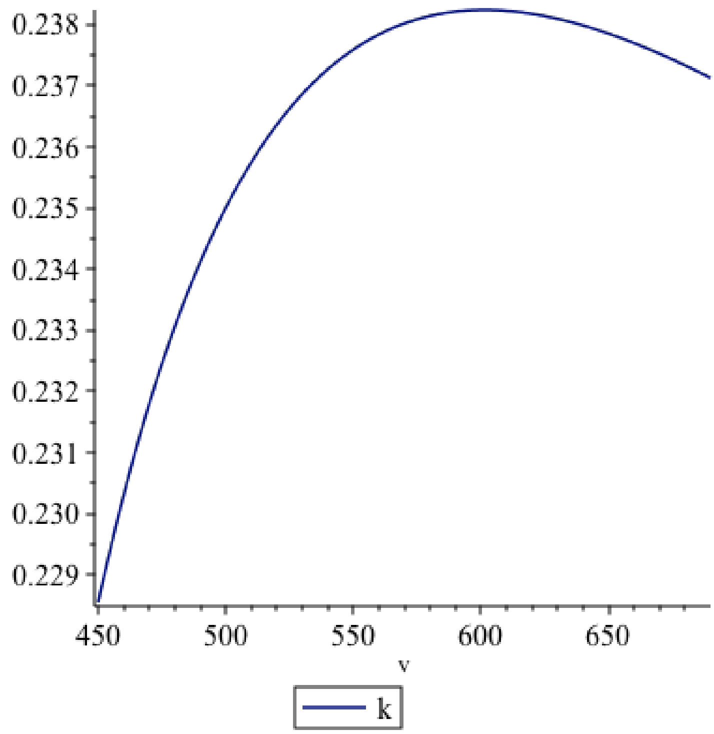

Figure 3: k as a function of v

Figure 3 plots k as a function of v. Consistent with Theorem 2.3.2, on the left side of the graph, $k(v)$ is an increasing function. This occurs because entrepreneurs are 'special' in the sense that it is difficult to locate agents of similar quality. As v rises, this distinction becomes less dramatic, and eventually k reaches a peak. Further increases in v above roughly 600 actual decrease k; bargaining power shifts back toward VCs as marginal entrepreneurs become more numerous.

3.1 Overinvestment Versus Underinvestment

The model may exhibit overinvestment in the sense of Myers and Majluf (1984). Specifically some 'lemon' entrepreneurs enter the market despite having negative-NPV projects. In our context, they hope that the VC obtains a good signal and funds their project. However, these marginal entrants would decline to self-fund their own projects if they were endowed with capital I.

These low-quality entrepreneurs pool with better quality entrepreneurs, thereby receiving favorable financing terms. Heuristically, in such cases the NPV of a funded project is equal to the true NPV of the project, plus the NPV of financing. For sufficiently high-quality firms, the NPV of financing is negative, and for sufficiently low quality firms the NPV of financing is positive. The marginal entrepreneur earns zero NPV by definition. But since he earns positive NPV from financing, it follows that he must earn negative NPV from his project.

On the other hand, the model may also exhibit underinvestment. In such cases, there are entrepreneurs who would fund their own projects (if they had sufficient capital) but who would be unwilling to approach VCs in our model. This occurs when the average VC skill is relatively poor and when there are limited benefits to pooling with better entrepreneurs.

We examine this issue by comparing p_{min} (the worst active entrepreneur) against the counterfactual p_f which is the worst entrepreneur that would be willing to self-fund his own project, given sufficient capital.

Let $PV(w_G, c, v)$ in (14) represent the value of a project.[6] Specifically, given the entrepreneur's quality p, the NPV of a self-funding project is:

$$p \times PV(w_G, c, v) - (I + D)$$

whereas the NPV of a VC-funding project is:

$$p \times [1 - \mathbb{E}\left(e | \, e_{max}\right)] \times \mathbf{V}^e\left(w_G, k, v\right) - D$$

[6]The key outcome of Baruch, Kim, and Yung (2024) indicates that, no matter whether a startup's project is venture-backed (therefore, having two entities) or self-financed with a single decision-maker, its value is identical to the first-best level. Hence, the paper indicates that VC financing is an efficient way of funding a project, and such an ownership structure is irrelevant to the firm's operation and value.

The NPV of financing is therefore defined as the difference between the two NPVs:

$$I - p \times \left[PV(w_G, c, v) - \left[1 - \mathbb{E}\left(e \middle| e_{max}\right)\right] \times \mathbf{V}^e\left(w_G, k, v\right)\right]$$

Equivalently, we define a project endowed with p as overinvestment if

$$p < \frac{I}{PV(w_G, c, v) - \left[1 - \mathbb{E}\left(e \middle| e_{max}\right)\right] \times \mathbf{V}^e\left(w_G, k, v\right)}$$

For $p = p_{min}$, the condition can be simplified as follows:

$$p_{min} < p_f := \frac{D + I}{PV(w_G, c, v)}$$

where p_f describes the level of p at which a self-financing entrepreneur's value is zero. Hence, we say that the VC market induces overinvestment if $p_{min} < p_f$, so there are entrepreneurs with $p \in [p_{min}, p_f)$ receiving funding. We describe under which conditions does the VC market induces overinvestment as follows:

We illustrate these properties using another numerical example under different assumptions and parameter values. In this analysis, we assume that both the VC and the entrepreneur qualities follow non-uniform distributions. As in the previous example, the VC quality e has a domain $(0,\frac{1}{2})$. Meanwhile, we assume that $e' := 2e$ follows Beta(α=8, β=2); thereby, high-quality VCs close to $e = 0$ are in extremely short supply. On the other hand, the entrepreneur quality p follows Beta(α=5, β=5), which is relatively balanced (less skewed) than that of the VC quality. For the rest of the analysis, we assign the parameter values as $w = 1.0$, $\mu = 0$, $\sigma = 0.5$, $\gamma = 0.5$, $\omega = 0.5$, $A = 15$, $D = 50$, $I = 200$, $c = 1$, and $v \in (350, 500)$.

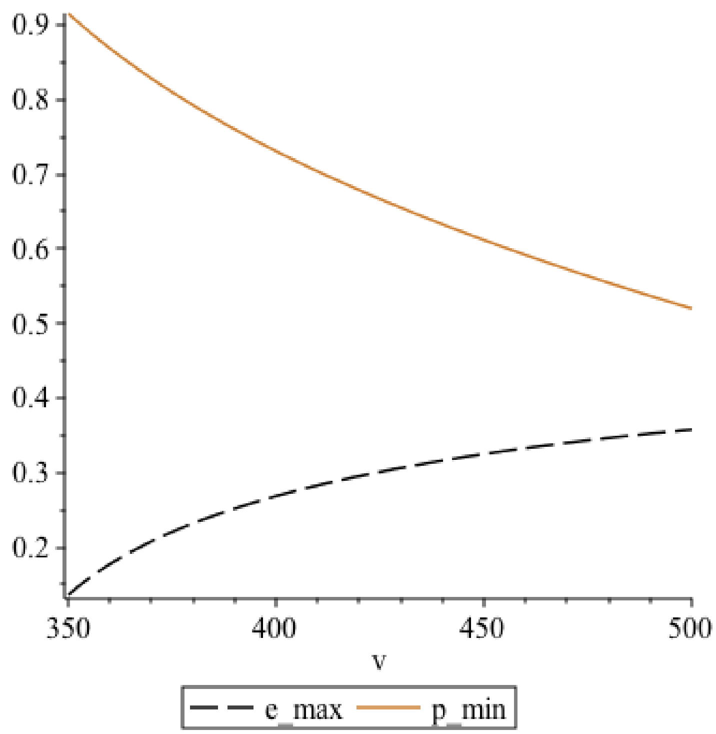

Figure 4: e_{max} and p_{min} as functions of v

Figure 4 shows the e_{max} and p_{min} associated with this equilibrium for each value of v. These shapes are again consistent with Theorem 2.3.1, as hot markets draw in new participants on both sides of the market by relaxing the entry hurdles.

Figure 5 depicts p_{min} and p_f. Under cold markets, the equilibrium exhibits underinvestment (i.e., $p_{min} > p_f$, so some projects with positive NPVs remain unfunded in the VC market). As the market gets hotter, it exhibits overinvestment in equilibrium, allowing entries of projects that could not have been launched under self-financing. In addition, the gap between p_{min} and p_f amplifies as v increases, implying that the overinvestment becomes more severe as the market heats.

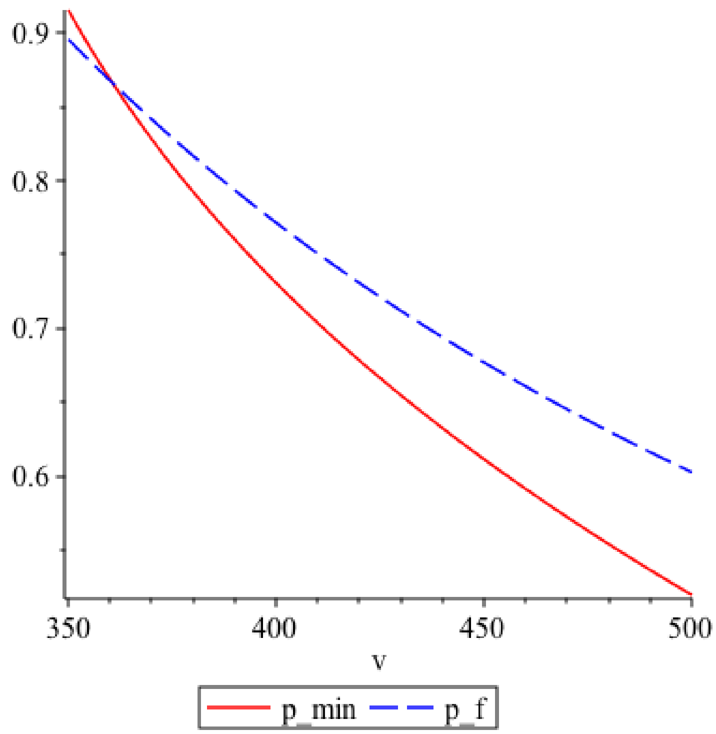

Figure 5: p_f and p_{min} as functions of v

We conclude that the equilibrium exhibits underinvestment when v is less than roughly 360, and exhibits overinvestment when v exceeds this value.

3.2 Sticky VC Supply

Consistent with Jovanovic and Szentes (2013), let us consider the market in which the VC supply is fixed with $e_{max} = \bar{e} \in (0,1)$. In this case, the market equilibrium comprises a system of the two equations:

$$J = \mathbf{V}^e\left(w_G, k, v\right) p_{min}\left[1 - \mathbb{E}\left(e \middle| \bar{e}\right)\right] - D = 0$$

$$H = F\left(\bar{e}\right) - \omega\left[1 - G\left(p_{min}\right)\right] = 0$$

subject to the marginal VC's incentive compatibility:

$$\left[\mathbf{V}^{vc}\left(w_G, k, v\right) - I\right] \mathbb{E}\left(p \middle| p_{min}\right)\left(1-\bar{e}\right) - I\left[1-\mathbb{E}\left(p \middle| p_{min}\right)\right]\bar{e} - A \geq 0$$

where

$$\mathbb{E}\left(e \middle| \bar{e}\right) := \frac{1}{F\left(\bar{e}\right)} \int_0^{\bar{e}} e dF\left(e\right)$$

Provided that $G\left(\cdot\right)$ is strictly monotone, the market-clearing condition is simplified as

$$p_{min} = G^{-1}\left(1 - \frac{F\left(\bar{e}\right)}{\omega}\right)$$

Then, we can solve for k as follows:

$$\mathbf{V}^{e}\left(w_G, k, v\right) \times G^{-1}\left(1 - \frac{F\left(\bar{e}\right)}{\omega}\right)\left[1-\mathbb{E}\left(e \middle| \bar{e}\right)\right] = D$$

and derive the following comparative static outcomes that represent how positive market shocks benefit the VC side with limited supply in the short run:

Theorem 3.1. *Short-run comparative static outcomes*

1. *The effect on k:*

$$\frac{\partial k}{\partial v} < 0,\ \frac{\partial k}{\partial \omega} < 0,\ \frac{\partial k}{\partial \bar{e}} > 0,\ \frac{\partial k}{\partial D} > 0$$

2. *In equilibrium, p_{min} is unaffected by (w_G, v, A, D), and*

$$\frac{\partial p_{min}}{\partial \bar{e}} < 0,\ \frac{\partial p_{min}}{\partial \omega} > 0$$

4 Concluding Remarks

In this paper, we study the source of bargaining power allocation between the entrepreneur and the VC of a startup. We address how the bargaining power and the initial contract term between entrepreneurs and VCs are endogenously determined in the market of talents. We build a Warlasian venture market where potential VCs and entrepreneurs are endowed with some talents required in the industry: for entrepreneurs, it is a likelihood of having a highly qualified idea, while for VCs, it is the ability to detect such good ideas.

We identify the determinants of endogenous bargaining power allocation in the market: i) public market valuations, ii) project characteristics, and iii) distribution of skills in the economy. Furthermore, we focus on how bargaining power varies as the market is heated up with higher public market valuations: i.e., which side of the market benefits more than the other during hot markets. We show that hot markets favor the party whose skills are less easily replaced at the current equilibrium, whose payoffs are less sensitive to this change, and the one who already s bargaining power.

Furthermore, the paper covers the issue of underinvestment and overinvestment in the industry: i.e., we analyze under which conditions the VC industry allows less qualified entrepreneurs to enter the market (overinvestment) and prohibits the entry of sufficiently qualified ones (underinvestment). We show that, provided that the distribution of the entrepreneurs' talents is sufficiently right-skewed, hot markets exacerbate the overinvestment problem in the VC industry.

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Appendix: Proof of Proposition 2.1

First, we compute the conditional probability Π', which corresponds to the incentive compatibility of a VC with talent e_j when she receives a high signal, $s_{i,j} = H$, from observing the idea of an entrepreneur with talent p_i. By its definition, we have

$$\Pi' := \Pr\left(w_i = w_G \middle|\, s_{i,j} = H,\ p_i \geq p_{min},\ e_j\right) = \frac{\Pr\left(w_i = w_G,\ s_{i,j} = H \middle|\, p_i \geq p_{min},\ e_j\right)}{\Pr\left(s_{i,j} = H \middle|\, p_i \geq p_{min},\ e_j\right)}$$

where the numerator is computed as

$$\begin{aligned}
\Pr\left(w_i = w_G,\ s_{i,j} = H \middle|\, p_i \geq p_{min},\ e_j\right) &= \Pr\left(s_{i,j} = H \middle|\, w_i = w_G,\ p_i \geq p_{min},\ e_j\right) \\
&\quad \times \Pr\left(w_i = w_G,\ p_i \geq p_{min},\ e_j\right) \\
&= \Pr\left(\epsilon_{i,j} = 0 \middle|\, w_i,\ p_i \geq p_{min},\ e_j\right) \times \Pr\left(w_i = w_G \middle|\, p_i \geq p_{min},\ e_j\right) \\
&\quad \times \Pr\left(p_i \geq p_{min},\ e_j\right) \\
&= (1 - e_j)\, \mathbb{E}\left(p \middle|\, p_{min}\right) \left[1 - G\left(p_{min}\right)\right]
\end{aligned}$$

and from the following computation

$$\begin{aligned}
\Pr\left(w_i = w_B,\ s_{i,j} = H \middle|\, p_i \geq p_{min},\ e_j\right) &= \Pr\left(s_{i,j} = H \middle|\, w_i = w_B,\ p_i \geq p_{min},\ e_j\right) \\
&\quad \times \Pr\left(w_i = w_B,\ p_i \geq p_{min},\ e_j\right) \\
&= \Pr\left(\epsilon_{i,j} = 1 \middle|\, w_i,\ p_i \geq p_{min},\ e_j\right) \times \Pr\left(w_i = w_B \middle|\, p_i \geq p_{min},\ e_j\right) \\
&\quad \times \Pr\left(p_i \geq p_{min},\ e_j\right) \\
&= e_j \left[1 - \mathbb{E}\left(p \middle|\, p_{min}\right)\right] \left[1 - G\left(p_{min}\right)\right]
\end{aligned}$$

we derive the denominator as the sum of the two terms above:

$$\begin{aligned}\Pr\left(s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right) &= \Pr\left(w_i=w_G,\ s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)\\ &\quad+\Pr\left(w_i=w_B,\ s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)\\ &=\left[1-G\left(p_i\right)\right]\times\left\{\left(1-e_j\right)\times\mathbb{E}\left(p\middle|\, p_{min}\right)+e_j\times\left[1-\mathbb{E}\left(p\middle|\, p_{min}\right)\right]\right\}\end{aligned}$$

Therefore, we have

$$\Pi'=\frac{\left(1-e_j\right)\mathbb{E}\left(p\middle|\, p_{min}\right)}{\left(1-e_j\right)\mathbb{E}\left(p\middle|\, p_{min}\right)+e_j\left[1-\mathbb{E}\left(p\middle|\, p_{min}\right)\right]}$$

Secondly, we derive the participant constraint of the VC with e_j, using the outcome above and (7). By the definition of its corresponding conditional probability

$$\Pi''':=\Pr\left(s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)$$

(7) is rearranged as

$$\Pr\left(w_i=w_G,\ s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)\times\left(\mathbf{V}^{vc}-I\right)-\Pr\left(w_i=w_B,\ s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)\times I-A\geq 0$$

or equivalently,

$$\mathbb{E}\left[\mathbf{1}_{\{w_i=w_G\}}\times\mathbf{1}_{\{s_{i,j}=H\}}\middle|\, p_i\geq p_{min},\ e_j\right]\times\left(\mathbf{V}^{vc}-I\right)-\mathbb{E}\left[\mathbf{1}_{\{w_i=B\}}\times\mathbf{1}_{\{s_{i,j}=H\}}\middle|\, p_i\geq p_{min},\ e_j\right]\times I-A\geq 0$$

Thirdly, we verify

$$\begin{aligned}\Pi'''\times\Pi' &= \Pr\left(s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)\times\frac{\Pr\left(w_i=w_G,\ s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)}{\Pr\left(s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)}\\ &=\Pr\left(w_i=w_G,\ s_{i,j}=H\middle|\, p_i\geq p_{min},\ e_j\right)\end{aligned}$$

Next, by the assumptions (1) and (2), we have

$$\underbrace{\Pr\left(\epsilon_{i,j}=0\middle|\, w_i,\ p_i \geq p_{min},\ e_j\right)}_{=1-e_j \text{ by assumption}} = 1-e_j$$

$$\Rightarrow \mathbb{E}\left[\underbrace{\Pr\left(\epsilon_{i,j}=0\middle|\, w_i,\ p_i,\ e_j\right)}_{=1-e_j \text{ by assumption}}\middle|\, w_i,\ p_i,\ e_j \leq e_{max}\right] = 1-\mathbb{E}\left(e\middle|\, e_{max}\right)$$

Finally, by using the law of iterated expectations, we verify

$$\begin{aligned}
\Pr\left(w_i=w_G,\ s_{i,j}=H\middle|\, p_i \geq p_{min},\ e_j\right) &= \mathbb{E}\left[\mathbf{1}_{\{w_i=w_G\}}\times\mathbf{1}_{\{s_{i,j}=H\}}\middle|\, p_i \geq p_{min},\ e_j\right] \\
&= \mathbb{E}\left[\mathbf{1}_{\{w_i=w_G\}}\times\mathbf{1}_{\{\epsilon_{i,j}=0\}}\middle|\, p_i \geq p_{min},\ e_j\right] \\
&= \mathbb{E}\left[\mathbb{E}\left(\mathbf{1}_{\{w_i=w_G\}}\times\mathbf{1}_{\{\epsilon_{i,j}=0\}}\middle|\, w_i,\ p_i \geq p_{min},\ e_j\right)\middle|\, p_i \geq p_{min},\ e_j\right] (LIE) \\
&= \mathbb{E}\left[\mathbf{1}_{\{w_i=w_G\}}\mathbb{E}\left(\mathbf{1}_{\{\epsilon_{i,j}=0\}}\middle|\, w_i,\ p_i \geq p_{min},\ e_j\right)\middle|\, p_i \geq p_{min},\ e_j\right] \\
&= \mathbb{E}\left[\mathbf{1}_{\{w_i=w_G\}}\left(1-e_j\right)\middle|\, p_i \geq p_{min},\ e_j\right] \\
&= \left(1-e_j\right)\mathbb{E}\left[\mathbb{E}\left(\mathbf{1}_{\{w_i=w_G\}}\middle|\, p_i,\ e_j\right)\middle|\, p_i \geq p_{min},\ e_j\right] (LIE) \\
&= \left(1-e_j\right)\mathbb{E}\left(p_i\middle|\, p_{min}\right)
\end{aligned}$$

and conclude that (7) is rearranged as

$$\mathbb{E}\left(p_i\middle|\, p_{min}\right)\times\left(1-e_j\right)\times\left(\mathbf{V}^{vc}-I\right)-\left[1-\mathbb{E}\left(p_i\middle|\, p_{min}\right)\right]\times e_j\times I-A \geq 0$$

Therefore, for a marginal VC with $e_j=e_{min}$, we derive her participation constraint as (10).

By (1) and (2), we have $\Pi'''' = p_i\left[1-\mathbb{E}\left(e\middle|\, e_{max}\right)\right]$ and thereby, for a marginal entrepreneur with $p_i=p_{min}$ is computed as (9).