The Effect of Capital Market Characteristics on the Value of Start-Up Firms*

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Abstract

We show that the success probability, financial contract, pre-money valuation, and value created in a start-up firm depend strongly on the characteristics of the capital market in which the start-up raises finance, such as the level of capital supply and degree of capital market competition, entry costs, and capital market transparency. We characterize the levels of capital supply and capital market competition for which the created surplus falls short of the second-best benchmark, implying that public policy measures affecting the supply of venture capital (e.g., changes in the capital gains tax) can increase welfare. We also investigate the effect of capital supply on the incentives of venture capitalists to screen projects. We show that screening is more intense if the level of capital supply is low, and less intense if it is high. The model is consistent with available empirical evidence and provides many new, testable implications.

1 Introduction

The venture capital market is highly cyclical, with persistent changes in supply and demand conditions (Gompers and Lerner (1999), Lerner (2002)). For instance, between the fourth quarters of 2000 and 2001 alone, fundraising dropped by more than 80 percent. The question we pursue in this paper is whether such changes in market conditions, and structural conditions of the venture capital market more generally, affect the value created in these firms.

Both anecdotal and empirical evidence suggests that the answer is yes. Gompers and Lerner (2000) find a strong positive relation between pre-money valuations and capital inflows, suggesting that "increases in the supply of venture capital may result in greater competition to finance companies and rising valuations". Rising valuations, in turn, imply greater ownership shares for entrepreneurs and lower shares for venture capitalists.[1] This in turn, affects incentives and thereby the value created in start-ups.

The link between ownership and incentives predicted by theory appears to be borne out in practice. For instance, Kaplan and Strömberg (2002) find that equity incentives increase the likelihood that venture capitalists will provide value-adding support activities. On the other hand, the drop in capital supply between 2000 and 2001 and the corresponding drop in valuations has raised concerns that the incentives of entrepreneurs might have dulled: "[I]f the investment climate is such that the founders see little hope of coming out with any serious money in their pockets [...] then, to the extent the founders and the executives are the same people, there is a morale problem. [...] They start plotting their next career move, perhaps with a competitor, from the date the deal is closed. In short, the VCs, while putting in place extremely favorable terms from their point of view, face the possibility of shooting themselves in the feet, particularly with respect to employee morale" (Bartlett (2001)).

To investigate the relation between capital market structure, incentives, and value creation, we embed venture capital contracting in a search market where entrepreneurs and venture capitalists bargain over financial claims. Bargaining powers depend on the relation between capital supply and demand. An increase in—say—capital supply makes it easier for an entrepreneur

[1] If V is the pre-money valuation and I is the venture capitalist's investment, the post-money valuation is $V+I$. The standard back-of-the-envelope formula for computing the venture capitalist's ownership share, γ, then gives $\gamma = I/(V+I)$, implying that $I = V(\gamma/(1-\gamma))$, where $\gamma/(1-\gamma)$ is an increasing function. Unless investment size increases proportionately, an increase in V therefore implies a decrease in γ.

to obtain financing, thus increasing his outside option in the bargaining. Our setup contrasts with the traditional financial contracting approach, which considers an isolated setting with one entrepreneur and one investor at a time, and a competitive capital market in the background in which entrepreneurs capture all the rents. In a world with many investors *and* many entrepreneurs, however, it is not clear why entrepreneurs should capture all the rents. On the contrary, anecdotal evidence suggests that the ability to extract rents varies over time along with changes in capital supply and demand. (See the above quote by Bartlett (2001).)

Transfers in rents due to changes in capital supply can be accomplished in different ways. We consider a stylized framework where the optimal financial contract consists of a risky, incentive-relevant, and a safe, incentive-irrelevant, claim.[2] Holding demand fixed, we show that different levels of capital supply entail different optimal forms of transferring rents. If capital is scarce rents are optimally transferred by shifting the risky claim. As the supply of capital increases, however, it becomes optimal to use the safe claim. As a third way of transferring rents we consider wages which—like the safe claim—have no incentive effect.

Building on Sahlman (1990), Kaplan and Strömberg (2001b, 2002), and Hellmann and Puri (2001), we model the relationship between the entrepreneur and venture capitalist as a two-sided incentive problem. Efficiency then requires striking a balance the entrepreneur's and the venture capitalist's ownership of the risky claim. The actual division of the risky claim, however, is determined by bargaining. During periods of high and low capital supply bargaining powers are strongly asymmetric, which implies the allocation of the risky claim deviates from the second-best optimum. Consequently, the net value created in start-ups is a hump-shaped function of capital supply. Provided efforts are complements, a similar picture emerges for the gross value, i.e., the value of the start-up if sold *after* effort and investment costs have been sunk (e.g., in an IPO or a private sale), as well as for the start-up's success probability. In situations where the capital supply is inefficiently low or high, public policy measures affecting capital inflows (e.g., changes in the capital gains tax) can thus increase welfare.

Changes in capital supply may be caused by political events—such as the abandonment of the "prudent man rule" in 1978—or by economic factors such as changes in entry costs. An

[2] To analyze value creation in start-ups it suffices to distinguish between incentive-relevant (i.e., risky) and incentive-irrelevant (i.e., safe) claims. Papers seeking to explain the rich cash-flow pattern in actual venture capital contracts are, e.g., Repullo and Suarez (2000), Schmidt (2000), and Hellmann (2001). These papers do not consider the interaction between capital market characteristics and optimal contracting, however.

important entry cost factor is the acquisition of knowledge and expertise. During the internet bubble in the 1990s entry costs appear to have fallen, leading to massive entry by new players from Wall Street and elsewhere.[3] After all, it is easier to advise a company selling dog food over the internet than advise a manufacturer of semiconductors. Free entry implies that in equilibrium venture capitalists must make zero profit. If entry costs decrease, the utility of a venture capitalist from being in the market must therefore decrease as well, implying that the level of competition among venture capitalists must rise. Interestingly, free entry does not imply efficiency. Since an individual venture capitalist entering the market does not take into account the effect of his entry on the overall level of capital supply, and hence on the bargaining, contracting, and value creation in other start-ups, entry entails a *contracting externality.*

We also study the role of capital market transparency. An increase in transparency has two effects. First, it amplifies the impact of capital market competition on the bargaining outcome. This benefits the "short" side of the market, i.e., the side which is relatively more scarce. Second, an increase in transparency reduces search frictions and therefore the cost of delay.

Changes in capital supply—and hence bargaining powers—not only affect incentives *after*, but also *prior* to the formation of a venture. In an extension of the model we consider the incentives of venture capitalists to screen between projects (or entrepreneurs) of low and high quality. We find that venture capitalists screen more if the level of capital market competition is low, and less if it is high.

We believe our model of contracting, bargaining, and search captures important features of real-world markets for start-up financing. In our model deals are struck through negotiations, and not through auctions or Walrasian tâtonnement.[4] Both entrepreneurs and investors must actively look for deals. They can quit negotiations at any time and team up with somebody else. Finally, finding a suitable partner takes time, and is easier the greater the supply of potential partners relative to the demand.

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[3] The Economist writes: "A host of new entrants are now dabbling in venture capital, ranging from ad hoc groups of MBAs to blue-blooded investment banks such as J.P. Morgan, to sports stars and even the CIA." (Money to Burn, the Economist, May 27, 2000). For a critical assessment, see Hellmann and Puri (2002).

[4] E.g., Bartlett (2002) notes: "The discussion starts out with the issue of valuation. The entrepreneur and his or her advisors lay on the table a number, based on art as much as science, and suggest that the venture capitalist agree with it as the basis for further discussion. [...] In fact, if a knowledgeable venture capitalist smells an auction, he or she will ordinarily pass and go on to the next opportunity. [...] The price, in other words, is usually left to naked negotiations between the buy and the sell side."

An interesting recent paper which also adopts a search market approach to start-up financing is Michelacci and Suarez (2000). Unlike this paper, Michelacci and Suarez do not consider incentive contracts or contracting inefficiencies. Rather, they focus on search inefficiencies, using an insight from the search literature that entry creates externalities for the matching chances of other market participants. Related is also Aghion, Bolton, and Tirole (2000). In their paper the limited partners in a venture partnership (i.e., the investors) must incentivize the venture capitalist to monitor an entrepreneur. Changes in market conditions that close the gap between the venture capitalist's opportunity cost of capital and the investors' cost of capital improve the incentive contract. Finally, Legros and Newman (2000) study the relation between the distribution of liquidity in the economy and the incentives of agents to engage in joint production. Unlike this paper, there is no investment to be financed—liqudity is used only to attract holders of complementary assets and to facilitate the trading of control rights.

The rest of the paper is organized as follows. Section 2 presents the model. The ratio of capital supply to demand—or degree of capital market competition—is assumed to be exogenous. Section 3 examines the long-run equilibrium with free entry. The degree of capital market competition is now endogenous. The focus in this section is on entry costs and capital market transparency. Section 4 discusses welfare and policy implications, while Section 5 considers the incentives of venture capitalists to screen projects. Section 6 concludes with a discussion of empirical implications. All proofs are in the Appendix.

2 Capital Market Structure and Value Creation

The model consists of three building blocks: financial contracting, bargaining, and search. We first derive the Pareto frontier characterizing the optimal financial contract for all feasible utility allocations. We explicitly allow the possibility that the venture capitalist pays the entrepreneur a wage. We then study Nash bargaining, where the bargaining solution selects a contract on the Pareto frontier. Outside options in the bargaining are taken as given. In a final step we endogenize outside options by embedding the bargaining problem in a search market. Outside options then depend on the level of capital market competition, or ratio of capital supply to demand. Throughout this section we take the level of capital market competition as given. It will be endogenized in Section 3 when we introduce free entry of capital.

2.1 Financial Contracting

We begin with the contracting environment. A penniless entrepreneur has a project which requires an investment $I > 0$. Financing is provided by a venture capitalist. The project payoff is $X_l \geq 0$ with probability $1 - p$ and $X_h > I > X_l$ with probability p. The success probability $p = p(e, a)$ depends on the entrepreneur's and venture capitalist's non-contractible efforts $e \in [0, 1]$ and $a \in [0, 1]$, respectively. Effort costs are strictly convex and denoted by $c_E(e)$ and $c_F(a)$, respectively. All agents are risk neutral.

The project payoff can be decomposed into two parts: a riskless payoff X_l and a risky payoff yielding nothing in the bad state and $\Delta_X := X_h - X_l$ in the good state. With the usual degree of caution we could label these claims debt (or liquidation preference) and equity. For the purpose of this paper such labelling is not important, however, since all that matters is that one claim is risky, i.e., incentive-relevant, while the other is not.

An optimal contract specifies (i) the venture capitalist's investment I, (ii) his holdings of the safe claim S, where $0 \leq S \leq X_l$, and (iii) his proportionate share of the risky claim $s \in [0, 1]$.[5] The remaining payoff goes to the entrepreneur. Later we will introduce the possibility that the venture capitalist pays the entrepreneur a wage. The entrepreneur's utility from the contract (s, S) is

$$U(s, S) := u(s) + X_l - S,$$

where $u(s) := p(1 - s)\Delta_X - c_E(e)$ denotes his (net) utility from owning a share $1 - s$ of the risky claim. Likewise, the venture capitalist's utility from the contract (s, S) is

$$V(s, S) := v(s) + S - I,$$

where $v(s) := ps\Delta_X - c_E(e)$ denotes his utility from owning a share s of the risky claim.

To simplify the exposition we proceed in two steps. We first derive the set of Pareto-optimal $u - v$ combinations generated by different allocations of the risky claim. We then add the safe claim and investment cost and derive the set of Pareto-optimal $U - V$ combinations.

The Pareto frontier characterizing the utilities $u(s)$ and $v(s)$ obtained from all Pareto-optimal allocations of the risky claim is denoted by $u = \psi(v)$. The Pareto frontier is defined on

[5] This rules out that an agent receives a higher payment in the bad state than in the good state. It is easy to show that such contracts are never optimal.

$v \in [\underline{v}, \overline{v}]$, where $\underline{v} \geq 0$. The correspondingIf $\underline{v} > 0$ this means it is never optimal to set $s = 0$, i.e., both the venture capitalist *and* the entrepreneur are better off if the venture capitalist holds a positive fraction of the risky claim.

The shape of this frontier will generally depend on the production technology $p(e, a)$. We focus on production technologies that are well behaved in the following sense:

(i) $\psi(v)$ is decreasing and strictly concave,

(ii) $u(s) + v(s)$ has a unique maximum in the interior of $[\underline{v}, \overline{v}]$, and

(iii) $v(s)$ is strictly increasing in s.

The first two properties follow naturally from the fact that the incentive problem is two-sided and effort costs are strictly convex. (The fact that $\psi(v)$ is decreasing follows from the definition of Pareto optimality.) Maximizing the sum of utilities then requires striking a balance between the two incentive problems. In particular, giving one agent too high a share of the risky claim decreases the total utility as this agent will then produce at a level where his marginal effort cost is comparatively high. Consequently, the allocation of the risky claim that maximizes total utility lies in the interior of the domain. Denote this allocation by $\hat{s}$ and the associated utility pair by $(\hat{v}, \hat{u})$. We henceforth refer to $\hat{s}$ as the *second-best allocation*. Evidently, it must hold that $\psi'(\hat{v}) = -1$. The third property states that the venture capitalist's utility is increasing in his share of the risky claim. Note that this property need not hold for dominated segments of the utility possibility frontier, i.e., segments that are not part of $\psi(v)$.

All three properties are natural and satisfied by a wide range of production technologies. In Appendix A we give two examples of technologies satisfying (i) to (iii) that are frequently used in the venture capital contracting literature: the linear technology $p(e, a) = da + (1 - d)e$ used by, e.g., Casamatta (2000), and the Cobb-Douglas technology $p(e, a) = a^d e^{1-d}$ used by, e.g., Repullo and Suarez (2000). Under the linear technology the two efforts are substitutes while under the Cobb-Douglas technology they are complements.[6] To make the problem nontrivial we finally assume that the second-best allocation is sufficiently profitable to allow the venture capitalist to break even, i.e., $\hat{v} > I$.

[6] Incidentally, under the Cobb-Douglas technology we have $\underline{v} > 0$: Since efforts are strongly complementary it is never Pareto optimal to have the entrepreneur hold all of the risky claim. By contrast, under the linear technology we have $\underline{v} = 0$, unless the venture capitalist is more productive than the entrepreneur, in which case we have $\underline{v} > 0$. See Appendix A for details.

We are now in the position to derive the Pareto frontier characterizing the utilities $U(s,S)$ and $V(s,S)$ for all Pareto-optimal contracts. The frontier is called *bargaining frontier* and denoted by $U = \Psi(V)$. The bargaining frontier is constructed from $\psi(v)$ by adding the safe claim in a way that minimizes incentive distortions. (Adding the investment cost is trivial as it is borne by the venture capitalist.) As an illustration, suppose $s > \hat{s}$, implying that the venture capitalist holds too much and the entrepreneur too little of the risky claim compared to the second-best allocation. It is easy to see that any Pareto-optimal contract where $s > \hat{s}$ must also have $S = X_l$, i.e., the venture capitalist must hold all of the safe claim. If this was not the case a Pareto-improvement would be possible whereby the entrepreneur trades in a fraction of his safe claim in return for a greater share of the risky claim, thereby moving closer toward the second-best allocation. Similarly, if $s < \hat{s}$ the entrepreneur must hold all of the safe claim, whereas if $s = \hat{s}$ any allocation of the safe claim is Pareto optimal.

The bargaining frontier thus consists of three parts: (i) a left, strictly concave interval with slope $\Psi'(V) \in (-1, 0)$, $s < \hat{s}$, and $S = 0$, (ii) a middle, linear interval with slope $\Psi'(V) = -1$, $s = \hat{s}$, and $S \in [0, X_l]$, and (iii) a right, strictly concave interval with slope $\Psi'(V) \in (-\infty, -1)$, $s > \hat{s}$ and $S = X_l$. By the definition of Pareto optimality the bargaining frontier is strictly decreasing. Figure 1a shows the construction of the bargaining frontier from $\psi(v)$ for the case where $\underline{v} = 0$, implying that $\max\{\underline{v} - I, 0\} = 0$. We have the following lemma.

Lemma 1. *The bargaining frontier takes the following form*:

$$\Psi(V) = \begin{cases} \psi(V + I) + X_l & \text{if } V \in [\max\{\underline{v} - I, 0\}, \hat{v} - I] \\ \psi(\hat{v}) + [X_l - I + \hat{v} - V] & \text{if } V \in [\hat{v} - I, \hat{v} + X_l - I] \\ \psi(V - X_l + I) & \text{if } V \in [\hat{v} + X_l - I, \overline{v} + X_l - I]. \end{cases} \tag{1}$$

Consider again Figure 1a. Moving along the bargaining frontier clockwise the entrepreneur's utility decreases and that of the venture capitalist increases. Utility is transferred from the entrepreneur to the venture capitalist in a Pareto-efficient way. In the left interval we have $s < \hat{s}$, implying that the entrepreneur holds too much of the risky claim compared to the second-best allocation. Utility is therefore transferred by reducing the entrepreneur's fraction of the risky claim. When the second-best allocation is reached the middle interval begins. In this interval utility is transferred by reducing the entrepreneur's holdings of the safe claim, which has no effect on incentives. Throughout the middle interval the net surplus $U + V$ thus remains constant and equal to the second-best value $\hat{v} + \hat{u} + X_l - I$. When the entrepreneur runs out of the safe claim the right interval begins. The only possible way to transfer utility is now to reduce the entrepreneur's fraction of the risky claim, which means the agents must deviate from the second-best allocation. Moving along the frontier clockwise the net surplus thus first increases (left interval), then it stays constant (middle interval), until it finally decreases (right interval).

The set of feasible contracts is enhanced if the venture capitalist can additionally pay the entrepreneur a wage, w. Paying a wage, like shifting the safe claim, has no incentive effect.[7] Consider again Figure 1a, now moving along the bargaining frontier *counter*clockwise from the right to the left. In the right interval we have $s > \hat{s}$, implying that the venture capitalist holds too much of the risky claim. Hence even if a wage payment is feasible, the *optimal* way to transfer utility is to reduce the venture capitalist's share of the risky claim. Paying a wage becomes an issue only for low levels of V. Rather than reducing s below $\hat{s}$ the venture capitalist can then preserve the second-best allocation by raising the entrepreneur's wage. Hence if wages are possible the linear, middle segment of the frontier extends to the left. Figures 1b and 1c show the bargaining frontier for different upper bounds of w. In Figure 1b the upper bound is $\overline{w} < \hat{v} - I$, in which case the middle interval of the bargaining frontier extends to $V \in [\hat{v} - I - \overline{w}, \hat{v} + X_l - I]$, while the left interval shrinks to $V \in [\max\{\underline{v} - I - \overline{w}, 0\}, \hat{v} - I - \overline{w}]$. In contrast, in Figure 1c the upper bound is $\overline{w} \geq \hat{v} - I$. In this case the venture capitalist's share of the risky claim never drops below $\hat{s}$, which implies the left, concave segment of the bargaining frontier vanishes entirely. Hence with potentially very large wage payments the second-best allocation can be preserved for low and intermediate values of V. For high values of V, however, it makes no difference if wage payments are possible.

While venture capital contracts frequently stipulate a wage for the entrepreneur, these wages are relatively small. The vast bulk of the entrepreneur's compensation is backloaded and comes in the form of financial claims. Hence from a practical point of view the most plausible case is Figure 1a or 1b. The theoretical argument for why large wage payments are rarely observed is that they might attract fraudulent entrepreneurs, or "fly-by-night operators" (Rajan), who cash in the wage but fail to deliver a profitable project (Rajan (1992), von Thadden (1995); in the context of venture capital finance: Hellmann (2002)). To limit the potential losses from attracting fraudulent entrepreneurs, compensation is primarily taken from the project payoff.[8] A

[7] In the absence of discounting it is irrelevant whether the wage is paid up front or ex post.

[8] The argument can be easily formalized by introducing a sufficiently large pool of "bad entrepreneurs" with projects generating a zero payoff in all states of nature.

second reason for why wage payments might be small has to do with incentive problems between the venture capitalist and his limited partners (Holmström and Tirole (1997), Michelacci and Suarez (2000)). To mitigate the problem the venture capitalist must put up a fraction of his own wealth, which naturally puts an upper bound on the maximum wage that can be paid to the entrepreneur.

2.2 Bargaining

The second building block of our model is bargaining. It is reasonable to assume that when bargaining over a contract the entrepreneur and the venture capitalist choose a contract that is Pareto efficient. Bargaining thus corresponds to choosing a utility pair (V, U) on the bargaining frontier. Let U^R and V^R denote the entrepreneur's and venture capitalist's reservation values—or outside options—in the bargaining. For the moment we take these outside options as given. Below we derive them endogenously as a function of supply and demand in the capital market. Our bargaining concept is the generalized Nash bargaining solution. Accordingly, the bargaining outcome consists of utilities $U = \Psi(V) \geq U^R$ and $V \geq V^R$ which maximize the *Nash product*

$$\left[V - V^R\right]^b \left[\Psi(V) - U^R\right]^{1-b}, \tag{2}$$

where $b \in (0, 1)$. For convenience, define $\beta := b/(1-b)$.

As the bargaining frontier is concave, the bargaining problem has a unique solution. Denote this solution by $\left(V^B, U^B\right)$, where $U^B = \Psi(V^B)$. We can restrict consideration to the case where the solution lies in the interior of the bargaining frontier's domain (see Proof of Proposition 1). Maxmizing (2) with respect to V we obtain the following Lemma.

Lemma 2. *The bargaining solution* $\left(V^B, U^B\right)$ *is given by*

$$\beta = -\frac{V^B - V^R}{U^B - U^R}\Psi'(V^B), \tag{3}$$

implying that V^B *is continuous and strictly increasing (decreasing) in* V^R *(in* U^R*).*

As is well known, the axiomatic Nash bargaining solution can be derived as the limit of a non-cooperative bargaining game where the two parties bargain with an open time horizon under the risk of breakdown (Binmore, Rubinstein, and Wolinsky (1986)). It is worth noting that our results do not depend on the specifics of the Nash bargaining solution. All that is needed is that an agent's bargaining utility is positively related to his own, and negatively related to his counterparty's outside option. Any bargaining concept with this feature delivers corresponding results.

2.3 Search

To endogenize outside options in the bargaining stage we embed the bargaining problem in a market environment. We consider a stationary search market populated by entrepreneurs and venture capitalists.[9] The measure of entrepreneurs and venture capitalists in the market is M_E and M_F, respectively. A key variable is the ratio of venture capitalists to entrepreneurs, or *degree of capital market competition*, $M_F/M_E =: \theta$.[10] A high value of θ implies that the capital market is strongly competitive.

Time is continuous. Both sides discount future utilities at the interest rate $r > 0$.[11] From the perspective of a venture capitalist the arrival rate of a deal is given by a decreasing function $q(\theta)$, where $\lim_{\theta\to 0} q(\theta) = \infty$ and $\lim_{\theta\to\infty} q(\theta) = 0$. Hence a venture capitalist is more likely to meet an entrepreneur in a given time interval if the ratio of venture capitalists to entrepreneurs is low. It is convenient to assume that $q(\theta)$ is continuously differentiable. Since the mass of deals per unit of time is $M_E q(\theta)$, the arrival rate of a deal from the perspective of an entrepreneur is $\theta q(\theta)$, which is increasing in θ. For convenience, define $q_F(\theta) := q(\theta)$ and $q_E(\theta) := \theta q(\theta)$.

To give an example, suppose the mass of deals per unit of time is given by the Cobb-Douglas matching technology $\xi[M_E M_F]^{0.5}$, where $\xi > 0$ is an efficiency measure. For instance, ξ could be a measure of market transparency: Matching is easier if the market is more transparent, which—holding market size constant—results in more deals per unit of time. Given this specification, arrival rates are $q_E(\theta) = \xi\theta^{0.5}$ and $q_F(\theta) = \xi\theta^{-0.5}$, respectively. We will return to this matching technology later.

If the search is successful the venture capitalist and the entrepreneur bargain over a con-

[9] In the search literature this framework is known as Diamond-Mortensen-Pissarides model (e.g., Pissarides (1990)). To our knowledge, however, incentive problems leading to a nonlinear bargaining frontier have hitherto not been analyzed in this framework.

[10] While in our model each venture capitalist can finance at most one project, all our results hold if venture capitalists can finance a finite number of projects. As each venture capitalist has a finite supply, θ is also a measure of the ratio of capital supply to the demand.

[11] For simplicity we assume that both sides use the same discount rate. Frictions are thus expressed as costs of delay. The model can be easily extended to include search costs.

tract.[12] Reservation values derive from the standard *asset value equations*[13]

$$rU^R = q_E(\theta)(U^B - U^R) \tag{4}$$

and

$$rV^R = q_F(\theta)(V^B - V^R). \tag{5}$$

If the venture capitalist and the entrepreneur reach an agreement they leave the market.[14]

Stationarity requires that the inflow of venture capitalists and entrepreneurs matches the outflow. Denote the measure of entrepreneurs and venture capitalists arriving in the market over one unit of time by m_E and m_F, respectively. The market is stationary if

$$q_F(\theta)M_F = m_F, \tag{6}$$

and

$$q_E(\theta)M_E = m_E. \tag{7}$$

As stationarity can always be ensured by scaling flows and stock accordingly, the market is fully characterized by the degree of capital market competition θ.

2.4 Value Creation in Start-Ups

The following definition summarizes the equilibrium conditions.

[12]The model can be extended (e.g., by introducing heterogeneity or match complementarities) such that on average a suitable partner is found only after several unsuccessful visits.

[13]Outside options can be valued as assets. Consider the entrepreneur's reservation value U^R. The (Poisson) arrival rate of a deal from the perspective of the entrepreneur is $q_E(\theta)$. The probability that a deal occurs in the next small time interval Δ is thus $q_E(\theta)\Delta$. With probability $1 - q_E(\theta)\Delta$ no deal occurs, and the entrepreneur continues searching. The expected discounted utility of the entrepreneur from searching is therefore

$$U^R = q_E(\theta)\Delta \exp(-r\Delta)\, U^B + (1 - q_E(\theta)\Delta) \exp(-r\Delta)\, U^R.$$

Solving for U^R and letting $\Delta \to 0$ using L'Hôpital's rule we have

$$U^R = \frac{q_E(\theta)U^B}{q_E(\theta) + r}.$$

Rearranging terms yields (4). The intuition underlying (5) is analogous.

[14]Recall that V^B is the venture capitalist's *net* payoff from bargaining. We thus implicitly assume that venture capitalists can invest their funds I at the interest rate r while searching for an investment opportunity.

Definition of Equilibrium. *An equilibrium in the market for start-up financing satisfies the following conditions.*

(i) The bargaining utilities $\left(V^B, U^B\right)$ *maximize the Nash product* (2).

(ii) The reservation values $\left(V^R, U^R\right)$ *satisfy the asset value equations* (4) *to* (5).

(iii) The flows and stocks of entrepreneurs and venture capitalists, (m_E, m_F) *and* (M_E, M_F), *satisfy the stationarity conditions* (6) *to* (7).

While the degree of capital market competition θ is exogenous, the utilities V^B, U^B, V^R, and U^R are endogenous. Finding the equilibrium utilities involves solving (3), (4), (5) and $U^B \equiv \Psi(V^B)$. Inserting (4) to (5) into (3), we have

$$\beta \frac{r + q_F(\theta)}{r + q_E(\theta)} = -\Psi'(V^B) \frac{V^B}{\Psi(V^B)}. \tag{8}$$

Hence the equilibrium is characterized by a single equation, (8), where $U^B \equiv \Psi(V^B)$. The properties of the equilibrium outcome are described in the following proposition. The key variable is the level of capital market competition, θ. For each level of capital market competition there exists a unique optimal contract and unique utilities V^B, U^B, V^R, and U^R.

Proposition 1. *For each level of capital market competition* θ *there exists a unique equilibrium. The venture capitalist's utility from the start-up* V^B *and his overall utility from being in the market* V^R *are both decreasing functions of* θ. *The converse holds for the entrepreneur.*

Increasing the level of capital market competition implies moving along the bargaining frontier from the right to the left. This has the following implications.

Case 1. *If wage payments are bounded by* $\overline{w} < \hat{v} - I$ *(Figures 1a-b) the net value created in the start-up* $U^B + V^B$ *is a hump-shaped function of* θ : *For low levels of capital market competition it is increasing in* θ, *for intermediate levels it is constant and equal to the second-best surplus* $\hat{v} + \hat{u} + X_l - I$, *while for high levels it is decreasing in* θ.

Case 2. *If the upper bound on wage payments exceeds* $\overline{w} \geq \hat{v} - I$ *(Figure 1c) the net value created in the start-up is a weakly increasing function of* θ : *For low levels of capital market competition it is increasing in* θ, *while for high levels it is constant and equal to the second-best surplus.*

Accordingly, bargaining and search utilities move in the same direction. Consider, for instance, the entrepreneur. An increase in the level of capital market competition makes it easier for the entrepreneur to find a counterparty, which reduces his cost of delay. Hence U^R increases (and V^R decreases), which implies the bargaining outcome shifts in favor of the entrepreneur. The resulting increase in U^B, in turn, feeds back into the search market dynamics. As the utility from doing a deal has gone up, searching for a deal becomes more valuable. The entrepreneur's search utility U^R therefore increases again, and so on. All together, an increase in the level of capital market competition, or—holding demand fixed—the level of capital supply, implies that we move along the bargaining frontier from the right to the left.

The rest follows from the construction of the bargaining frontier. Consider again Figures 1a-c. If the level of capital market competition is low the bargaining outcome lies in the right, concave interval of the frontier. As the level of capital market competition increases the venture capitalist shifts utility to the entrepreneur by reducing s. The division of the risky claim thus gradually approaches the second-best, implying that the net surplus $U^B + V^B$ increases. Once the second-best allocation $\hat{s}$ is reached, utility is either transferred via the safe claim or via a wage payment. In either case the net surplus remains constant and equal to the second-best value $\hat{v} + \hat{u} + X_l - I$. If the upper bound on w is sufficiently large (Case 2 and Figure 1c), the second-best allocation can be maintained even for high levels of capital market competition. As argued earlier, wage payments by venture capitalists are typically small, implying that this case is less likely to be relevant. By contrast, if the upper bound on w is zero or sufficiently small (Case 1 and Figures 1a-b), high levels of capital supply require that the venture capitalist reduces s below $\hat{s}$. In this case *an increase in capital supply—or the level of capital market competition—reduces the net surplus created in the start-up.* The resulting policy implications are discussed in Section 4.

While the focus of Proposition 1 is on value creation, it has immediate implications for the (pre-money) *valuation* of start-ups.[15] As briefly laid out in the Introduction (footnotes 3 and 6), the valuation is a hypothetical figure agreed upon by the venture capitalist and the entrepreneur to determine the venture capitalist's return from his investment. Ceteris paribus, a high valuation implies that the venture capitalist earns a low return, and vice versa. In the current setting the appropriate measure of the venture capitalist's profit is V^B, which is what he is left with after investment and effort costs have been deducted. Given the inverse relation between the pre-money valuation and the venture capitalist's net profit, the following result follows immediately from Proposition 1.

[15] We thank Thomas Hellmann for suggesting this extension.

Corollary 1. *The (pre-money) valuation of the start-up is strictly increasing in the level of capital market competition* θ.

Corollary 1 is a natural result in any setting where bargaining powers depend on the level of capital market competition. As the level of capital market competition goes up the venture capitalist's bargaining power becomes weaker, which implies the pre-money valuation increases and the venture capitalist's profit decreases.

Finally, observe that in all three figures the bargaining frontier is decreasing and strictly concave for low levels of capital market competition, or high values of V. Hence regardless of whether high wage payments are feasible or not, if the level of capital market competition is low an increase in competition increases the net value created in start-ups. Similarly, if the level of capital market competition is low a change in θ always affects the division of the risky claim between the venture capitalist and the entrepreneur. By contrast, for intermediate levels of capital market competition the riskiness of the venture capitalist's and entrepreneur's claims remains constant, while for high competition levels the answer depends on whether w is bounded or not. The effect of a change in the competition level on the riskiness of the agents' claims is summarized in the following proposition. The proof follows immediately from the way the bargaining frontier is constructed and the fact that an increase in the level of capital market competition induces a move along the bargaining frontier from the right to the left.

Proposition 2. *If the level of capital market competition* θ *is low an increase in* θ *increases (reduces) the riskiness of the entrepreneur's (venture capitalist's) claim.*

For intermediate levels of capital market competition a change in θ *has no effect on the agents' risk exposure: The venture capitalist and the entrepreneur continue to hold a constant fraction* $\hat{s}$ *and* $1-\hat{s}$ *of the risky claim, respectively.*

Finally, if the level of capital market competition is high an increase in θ *has either the same effect as if* θ *is low (if* $\overline{w} < \hat{v} - I$*), or it has no effect on the riskiness of claims (if* $\overline{w} \geq \hat{v} - I$*).*

2.5 Market Value and Success Probability

Measuring the net surplus $U^B + V^B$ is not straightforward as it is defined net of effort costs. From an empirical perspective an important measure is therefore the gross surplus, or *market value* $p(e,a)\,\Delta_X + X_l$. It denotes the expected return after effort and investment costs have been sunk, but before cash flows are realized. In other words, the market value is what the entrepreneur and the venture capitalist could hope to receive if the firm was sold at an interim date, e.g., via a private sale or IPO. The functional behavior of the market value is the same as that of the *success probability* $p(e,a)$.

Unlike the net surplus $U^B + V^B$, the success probability is not necessarily a hump-shaped function of s or the level of capital market competition. Its functional behavior depends on whether the two efforts are complements or substitutes. To explore this issue, consider the CES technology $p(e,a) = (da^\rho + (1-d)e^\rho)^{\frac{1}{\rho}}$, where $\rho \leq 1$ and $d \in (0,1)$. The parameter ρ measures the degree of complementarity between the two efforts. If $\rho = 1$ the two efforts are substitutes and the CES technology coincides with the linear technology. By contrast, if $\rho < 1$ the two efforts are complements. To obtain a closed-form solution, we assume quadratic effort costs $c_E(e) := e^2/2\alpha_E$ and $c_F(a) := a^2/2\alpha$, respectively.

Consider first the case where the two efforts are complements. It is straightforward to show that the equilibrium success probability $p^*(s) := p(e^*(s), a^*(s))$ is a hump-shaped function of s with interior maximum at

$$s_p^* := \frac{1}{1+\phi}, \text{ where } \phi := \left[\left(\frac{\alpha_E}{\alpha_F}\right)^{\frac{\rho}{2}}\left(\frac{1-d}{d}\right)\right]^{\frac{1}{1-\rho}}.$$

Note that the value of s that maximizes the gross surplus (or success probability), s_p^*, is generally not the same as that which maximizes the net surplus, $\hat{s}$, as the latter takes into account effort costs while the former does not. Given the inverse relation between s and the level of capital market competition θ, an increase in θ has a positive effect on the market value and success probability if θ is low, and a negative effect if θ is high.

If the two efforts are perfect substitutes the equilibrium success probability is a monotonic function of s. The parameter $\phi > 0$ measures the productivity of the entrepreneur relative to the venture capitalist. If $\phi > 1$ the entrepreneur is more productive, which means his effort is less costly and/or the success probability is more responsive to his effort. In this case the market value and success probability are decreasing (increasing) functions of s (of θ). By contrast, if $\phi < 1$ the venture capitalist is more productive, in which case the market value and success probability are increasing (decreasing) functions of s (of θ). The case where the two efforts are perfect substitutes is extreme, however, and less likely to be empirically relevant.

Combining these insights with Proposition 1 we have the following result.

Proposition 3. *If efforts are complements the start-up's market value and success probability* *are either hump-shaped functions of the level of capital market competition θ (if $\overline{w} < \hat{v} - I$), or they are increasing in θ for low levels of capital market competition but constant for high levels of capital market competition (if $\overline{w} \geq \hat{v} - I$).*

If efforts are perfect substitutes the market value and success probability are either weakly increasing (if the entrepreneur is more productive) or weakly decreasing functions of θ (if the venture capitalist is more productive).

In all of the above cases the function mapping θ into the market value and success probability has a flat segment, which arises from the fact that either the safe claim or a wage payment is used to transfer utility. As argued earlier, the empirically relevant case is likely to be the one where $\overline{w} < \hat{v} - I$. Accordingly, if the two efforts are complements too high a level of capital market competition—or capital supply—not only reduces the net surplus created in start-ups, but also the start-up's market value and success probability.

3 Entry Costs and Capital Market Transparency

Thus far we have taken the level of capital market competition as given. We now consider the long-run equilibrium in which the supply of capital adjusts optimally to changes in exogenous factors. The focus of this section is on entry costs and capital market transparency.

3.1 Entry Costs

We take as given the flow of new ideas that are continuously created in the economy. Each idea is associated with an entrepreneur and cannot be traded. We normalize the flow of new ideas such that the mass $m_E = 1$ of ideas is created in the market during one unit of time. The inflow of capital is endogenous and determined by a zero-profit constraint. We assume that a venture capitalist entering the market incurs entry cost $k > 0$, which may be conveniently thought of as the cost of setting up a business, raising funds, and acquiring knowledge and expertise. As argued in the Introduction, entry costs appear to have fallen during the internet bubble, leading to massive entry by new players from Wall Street and elsewhere. Zero profit implies that $V^R = k$, i.e., the utility realized by a venture capitalist in the market must be positive and equal to the entry cost. The equilibrium conditions are the same as before, except that $m_E = 1$ and $V^R = k$. Finally, the market will open up only if venture capitalists can *potentially* break even, i.e., if $\overline{v} + X_l - I > k$. We assume that this holds.

While it seems reasonable to assume that the supply of capital adjusts more quickly to changes in exogenous factors than the supply of new ideas, the model can be easily extended to incorporate endogenous entry by both venture capitalists and entrepreneurs. Suppose, for instance, entrepreneurs face entry costs $c \in [0, \overline{c}]$. If $\overline{c}$ is sufficiently large there exists a threshold $\hat{c} < \overline{c}$ such that all entrepreneurs with cost $c \leq \hat{c}$ enter the market. This setting, in particular, generates exactly the same results as the setting considered here.

Consider now a decrease in entry cost. From the equality $V^R = k$ we have that the utility realized by a venture capitalist in the market V^R must decrease by the same amount. Since V^R and the level of capital market competition θ are inversely related (Proposition 1), this implies that the level of capital market competition must increase. In short, a drop in entry costs increases the supply of capital in the market.

Proposition 4. *For each level of entry cost k there exists a unique equilibrium associated with a unique level of capital market competition θ. A decrease in k leads to an increase in θ, and vice versa. The effect of k on the net surplus, riskiness of financial claims, market value, and success probability then follows from Propositions 1-3 and Corollary 1.*

While entry is endogenous, the resulting allocation is generally not second-best optimal. If entry costs are high the supply of capital is too low relative to the second-best, implying that the associated net surplus $U^B + V^B$ is inefficiently low. Similarly, if entry costs are low and wage payments are not too high (Case 1 in Proposition 1), the level of capital supply is inefficiently high. Hence while the decision to enter is individually rational, it may be socially suboptimal: An individual venture capitalist entering the market does not take into account the effect of his entry on the overall level of capital supply—or capital market competition—and thus on the contracting, incentives, and value creation in other start-ups. Entry by an individual venture capitalist therefore either entails a positive or negative *contracting externality*, depending on whether the existing level of capital market competition is below or above the second best. This externality is, to our knowledge, new and has not been discussed elsewhere.

3.2 Capital Market Transparency

Technological innovations such as the internet, but also the regional concentration of venture capitalists in Silicon Valley and Boston's Route 128 had a positive impact on transparency in the market for start-up financing. Consider the Cobb-Douglas matching technology introduced in

Section 2.3. According to this specification, the mass of new deals per unit of time is $\xi[M_E M_F]^{0.5}$, where $\xi > 0$ is a measure of market transparency or—more generally—market efficiency.

An increase in market transparency has two effects. The first is that it amplifies the effect of changes in the level of capital market competition on the bargaining outcome, and hence on the contracting and value creation in start-ups. The second effect is that it reduces search frictions and therefore the cost of delay.

Consider first the amplification effect. Inserting the reservation values (4) to (5) in the first-order condition characterizing the bargaining outcome (3) yields

$$\beta \frac{r + \xi\theta^{-\frac{1}{2}}}{r + \xi\theta^{\frac{1}{2}}} = -\Psi(V^B)\frac{V^B}{\psi(V^B)}. \tag{9}$$

Implicitly differentiating V^B with respect to ξ shows that if $\theta < 1$—i.e., if venture capitalists constitute the "short side" of the market—an increase in transparency improves the bargaining utility of a venture capitalist. If $\theta > 1$ it has the opposite effect. Intuitively, the greater the transparency the more pronounced is the impact of capital market competition on the bargaining outcome. As this benefits the short side of the market the bargaining utility of this side increases. Moreover, the cross-derivative of V^B with respect to θ and ξ is negative. Hence the greater the market transparency the bigger is the move along the bargaining frontier as the level of capital market competition changes. A greater market transparency thus amplifies the impact of supply and demand on the bargaining outcome.

Second, an increase in transparency reduces frictions and therefore the cost of delay. In principle, this implies that both the entrepreneur's and the venture capitalist's utility from being in the market, U^R and V^R, must rise. But V^R cannot rise as it is determined by the free-entry condition $V^R = k$. To ensure that V^R remains constant the venture capitalist's bargaining utility must therefore decrease. Hence under this second effect both the entrepreneur's bargaining utility U^B and his overall utility from being in the market U^B must increase. By contrast, the venture capitalist's bargaining utility V^B decreases, while his overall utility V^R remains equal to k.

Accordingly, if venture capitalists constitute the long side of the market both effects go in the same direction. By contrast, if venture capitalists constitute the short side of the market the two effects go in different directions, implying that the overall effect is ambiguous. This is summarized in the following proposition.

Proposition 5. *If venture capitalists constitute the long side of the market* ($\theta > 1$)*, an* *increase in transparency has the same effect as an exogenous increase in the level of capital market competition, and vice versa. The effect on the net surplus, riskiness of financial claims, market value, and success probability then follows from Propositions 1 to 3 and Corollary 1.*

If venture capitalists constitute the short side of the market ($\theta < 1$), the effect of a change in capital market transparency is ambiguous.

Given the one-to-one correspondence between entry costs and the level of capital market competition (Proposition 4), the case where venture capitalists constitute the long side of the market corresponds to the case where entry costs are low. In this case an increase in transparency implies a counterclockwise move along the bargaining frontier, with the consequences described in Propositions 1 to 3 and Corollary 1. In particular, if $\overline{w} < \hat{v} - I$—i.e., if the wage paid to the entrepreneur is sufficiently small—we know that moving along the bargaining frontier counterclockwise will at some point reduce the overall value created in the venture. Hence an increase in transparency need not always be beneficial: If entrepreneurs already have too much bargaining power an increase in transparency may push the allocation further away from the second-best optimum.

4 Welfare and Policy Implications

The main insight from this paper is that the surplus created in start-ups depends on the level of capital supply and degree of competition in the capital market. In particular, if the level of competition is low the ensuing surplus is strictly less than the second-best surplus. If wage payments from the venture capitalist to the entrepreneur are small ($\overline{w} < \hat{v} - I$) this also holds for high competition levels. In both cases a regulator, by affecting entry costs (e.g., through a change in the capital gains tax) and hence capital inflows, can improve welfare. What is important is that the regulator need not directly interfere in the bargaining or contracting. All he needs to do is implement a level of capital market competition under which bargaining powers are such that the venture capitalist and the entrepreneur settle on the second-best allocation.

Since financing takes place in a market with frictions, the surplus created in start-ups captures only part of the social surplus. The other part is the utility loss due to search frictions, which in our model comes as cost of delay. (As noted earlier, the model can be easily extended to include search costs.) A welfare criterion taking into account both aspects are the steady-state gains realized by all market participants minus entry costs, i.e.,

$$W := V^R + U^R - k. \tag{10}$$

In a market with free entry we have $V^R = k$, which implies (10) reduces to $W = U^R$, i.e., social welfare equals the utility realized by a new cohort of entrepreneurs in the market.

As a benchmark, consider the case where there are search frictions but no moral hazard. In the absence of moral hazard the bargaining frontier is linear with slope equal to minus one. The welfare-maximizing level of θ is therefore that which minimizes search frictions. Straightforward calculations show that the welfare-maximizing level of θ satisfies

$$-\frac{q_F(\theta)}{q'_F(\theta)}\frac{q'_E(\theta)}{q_E(\theta)}\frac{r+q_F(\theta)}{r+q_E(\theta)} = \frac{V^B}{U^B}. \tag{11}$$

By contrast, the equilibrium in our model is characterized by equation (8):

$$\beta\frac{r+q_F(\theta)}{r+q_E(\theta)} = -\Psi'(V^B)\frac{V^B}{\Psi(V^B)},$$

where $U^B \equiv \Psi(V^B)$. In the absence of moral hazard we have $\Psi'(V^B) = -1$, implying that the equilibrium coincides with the welfare-maximizing outcome if and only if β equals the ratio of elasticities of arrival rates, $[q'_E(\theta)/q_E(\theta)]/[q'_F(\theta)/q_F(\theta)]$. In the search and matching literature this is known as Hosios' condition (Hosios (1990)). Evidently, this condition will generally not hold. The good news, however, is that the welfare-maximizing outcome can be easily attained by appropriately taxing or subsidizing capital inflows, thereby changing the level of capital market competition θ. See Michelacci and Suarez (2000) for details.

If in addition to search frictions there is also moral hazard, the welfare-maximizing level of θ is given by

$$-\frac{q_F(\theta)}{q'_F(\theta)}\frac{q'_E(\theta)}{q_E(\theta)}\frac{r+q_F(\theta)}{r+q_E(\theta)} = \frac{-1}{\Psi'(V^B)}\frac{V^B}{\Psi(V^B)}. \tag{12}$$

To our knowledge, (12) is new to the search and matching literature, which typically considers a linear bargaining frontier. As is easy to see, unless $\Psi'(V^B) = -1$, i.e., unless the bargaining outcome lies on the linear segment of the bargaining frontier, (12) and (11) do not coincide. Under moral hazard, a welfare-maximizing regulator will thus not necessarily implement a value of θ that mininimizes search frictions. The problem is that he has only one instrument (viz., θ) but two problems to fix: (1) minimizing search frictions, and (2) reallocating bargaining powers in a way such that the agents agree on the second-best allocation. Unless the value of θ that solves (1) also solves (2) the regulator will have to strike a balance between the two problems, and welfare will be strictly lower than in the absence of moral hazard.

5 Project Screening

Changes in the level of capital supply not only affect incentives after, but also prior to the formation of a start-up. In this section we consider the incentives of venture capitalists to screen projects, a function that—besides providing capital and coaching projects—is key to the venture capital business. Suppose projects (or entrepreneurs) come in two qualities, or types: $t \in T := \{L, H\}$. The probability that a project is a high-quality project is $\pi > 0$. Only high-quality projects are profitable. For simplicity, suppose the low-quality project yields a zero payoff for sure. A priori, neither the venture capitalist nor the entrepreneur know the project's quality. The venture capitalist can, however, discover the project's quality by incurring a screening cost $C > 0$.

In what follows we show that venture capitalists are less likely to screen projects if the level of capital market competition is high. This is consistent with casual evidence that tapping venture capital is easier in times when the venture capital market is booming. Before stating the result let us briefly lay out the argument. Each venture capitalist can finance and coach only a finite number of projects. For simplicity, we assume in our model that this number is one. Before sinking time and capital into a project a venture capitalist will weigh the benefits from doing so against the opportunity cost of (not) searching for a better candidate. If this opportunity cost is high the venture capitalist will carefully screen the project before making the investment. If the opportunity cost if low the benefits from screening are also low. The opportunity cost, i.e., the utility from searching for an alternative candidate, is V^R. With free entry this opportunity cost is fixed at $V^R = k$, implying that venture capitalists are more likely to screen if entry costs are high, or—drawing on Proposition 4—if the level of capital market competition is low.

The sequence of moves is as follows. The venture capitalist and the entrepreneur bargain over a contract which grants the venture capitalist the right to withdraw if he finds out that the project quality is low. Subsequently the venture capitalist decides whether to screen or not. If he screens he learns the project's quality for sure. If he does not screen he continues to hold prior beliefs that he faces a high-quality project with probability π. If the venture capitalist does not withdraw after the screening he finances the investment. After the investment cost is sunk the project quality is fully revealed. This last assumption simplifies the analysis as it implies that effort choices are made under complete information.

In accordance with our previous notation, denote the venture capitalist's expected utility from investing in a high-quality project by V^B. Clearly, if the venture capitalist screens and finds out that the project quality is low he will not invest but search anew. Moreover, as a low-quality project yields a zero payoff for sure it does not pay an entrepreneur who has been screened and rejected to stay in the market.[16] The expected utility from screening is thus $\pi V^B + (1-\pi)V^R - C$. By contrast, the expected utility from not screening is $\pi V^B - (1-\pi)I$.[17] Given the zero-profit constraint $V^R = k$, screening is optimal if and only if

$$C \leq (1-\pi)(k+I). \tag{13}$$

From Proposition 4 we know that for each level of entry cost k there exists a unique level of capital market competition θ. We thus have the following result.

Proposition 6. *Ceteris paribus, screening is more likely if* (*i*) *the cost of screening* C *is low,* (*ii*) *the fraction of low-type projects* $1-\pi$ *is large,* (*iii*) *the investment outlay* I (*which is lost if a low-quality project is financed*) *is large, and* (*iv*) *entry costs* k *are high—or alternatively—the degree of capital market competition* θ *is low.*

6 Concluding Remarks

In this paper we show that financial contracts, the success probability, valuation, and value created in start-up firms depend on characteristics of the capital market in which these firms raise finance, such as the level of capital supply or degree of capital market competition, entry costs, and capital market transparency. To the extent that capital inflows vary over the business cycle (Gompers and Lerner (1999), Figure 1.1), our theory postulates a relation between the value created in start-ups and the general economic environment.

Gompers and Lerner (2000) test the relation between pre-money valuations and capital inflows. In accord with our model, they find a strong positive relation between the two variables. Unless investment size increases correspondingly, this also implies that entrepreneurs obtain a greater share of the firm if the supply of venture capital is abundant, as predicted by our

[16] This rules out the possibility of (negative) *pool externalities* (Broecker (1990)).

[17] Since the market is stationary there are only two equilibrium strategies: (i) screening and investing if and only if the project quality is high, and (ii) investing without screening. Since utilities get discounted it is never optimal to search for one more period and then do either (i) or (ii) in the following period. Evidently, it is also not an equilibrium strategy to *always* search, i.e., to never do either (i) or (ii).

model. Other implications of our model are consistent with anecdotal evidence, such as the shift in bargaining powers and incentives due to changes in capital supply (Bartlett (2001a)), or the fact that prior to the peak of the internet bubble—when capital supply was abundant and competition between investors fierce—an increasing number of unsound businesses received funding. The latter observation is consistent with Section 5 of our model where the argument is that the return to screening is low in times when the capital supply is high. It is, of course, also consistent with behavioral arguments. Finally, Gompers and Lerner (2000) examine the relation between capital market competition and the success of new ventures. The authors find no statistically significant difference for investments made during the late 1980s, a period when capital market competition was strong, and the early 1990s, a period of relatively low inflows and weak competition. This is consistent with the hump-shaped relation predicted by our model, which implies that the success rate will be small if competition is either strong or weak. It is, however, also consistent with the hypothesis that there is no relation between competition and success. To distinguish between the two hypotheses more than two periods will be needed.

Our model can be extended in several directions. As it stands, the focus is on cash-flow rights. Real-world venture capital contracts, however, include cash-flow rights, voting rights, liquidation rights, board rights, and other instruments (Kaplan and Strömberg (2001a)). One possible avenue of research is to investigate how changes in capital supply affect the *mix* of different contractual provisions. Again, the underlying principle will have to be that utility is transferred in a way that minimizes incentive distortions. Second, our model treats venture capitalists as a single entity. In practice, venture capital partnerships consist of general and limited partners, which are tied together by a contract. It might be worthwile to analyze how changes in capital market competition simultaneously affect both, the contract between the venture capitalist and the entrepreneur on the one hand and that between the venture capitalist and his limited partners on the other hand. Third, while in our model project outcomes depend on effort choice, we do not directly allow for project choice. Suppose there is a choice between projects that rely heavily on the effort of a venture capitalist and projects that do not. If the level of capital market competition is strong and the venture capitalist's equilibrium equity stake becomes small, it might become optimal to switch from effort-intensive projects—such as early-stage seed financing—toward projects that require less coaching and value-added support.

7 Appendix

7.1 Appendix A: Well-Behaved Production Technologies

Linear Technology. To obtain a closed-form solution we assume quadratic effort costs: $c_E(e) := e^2/2\alpha_E$ and $c_F(a) := a^2/2\alpha$, respectively. Moreover, to ensure that the equilibrium success probability has an interior solution we assume that $\max\{\alpha_E(1-d), \alpha_F d\} < 1/\Delta_X$. Given some allocation s the corresponding equilibrium effort choices are then $a^*(s) = \alpha_F d s \Delta_X$ and $e^*(s) = \alpha_E(1-d)(1-s)\Delta_X$, respectively. The equilibrium success probability is

$$p^*(s) := p(e^*(s), a^*(s)) = \Delta_X \left[\alpha_F d^2 s + \alpha_E (1-d)^2 (1-s)\right].$$

The venture capitalist's and the entrepreneur's utility under the allocation s is

$$v(s) = \frac{1}{2}\alpha_F d^2 s^2 \Delta_X^2 + \alpha_E (1-d)^2 s (1-s) \Delta_X^2 \tag{14}$$

and

$$u(s) = \frac{1}{2}\alpha_E (1-d)^2 (1-s)^2 \Delta_X^2 + \alpha_F^2 d^2 s (1-s) \Delta_X^2, \tag{15}$$

respectively.

The Pareto frontier derives from the following maximization program: The entrepreneur choose s to maximize $u(s)$ subject to the constraint that $v(s) \geq v$. The solution is characterized for all feasible reservation values $v \geq 0$. (If v is too large the solution is not feasible). In a slight abuse of notation we denote the solution by $s^*(v)$. From (14) and (15) it follows that $v(s)$ and $u(s)$ are both strictly quasiconcave. Accordingly, s^* is a solution to the entrepreneur's problem if and only if $v(s)$ is nondecreasing and $u(s)$ is nonincreasing at s^*. Define

$$\underline{s} := \frac{\alpha_F d^2 - \alpha_E (1-d)^2}{2\alpha_F d^2 - \alpha_E (1-d)^2}$$

and

$$\overline{s} := \frac{\alpha_E (1-d)^2}{2\alpha_E (1-d)^2 - \alpha_F d^2},$$

where $0 < \underline{s} < \overline{s} < 1$. We obtain the following result:

(i) if $\alpha_E (1-d)^2 > \alpha_F d^2$ the set of Pareto-optimal allocations is $[0, \overline{s}]$,

(ii) if $\alpha_E (1-d)^2 = \alpha_F d^2$ the set of Pareto-optimal allocations is $[0, 1]$, and

(iii) if $\alpha_E (1-d)^2 < \alpha_F d^2$ the set of Pareto-optimal allocations is $[\underline{s}, 1]$.

In Case (i) define $\underline{v} := 0$ and $\overline{v} =: v(\overline{s})$. In Case (ii) define $\underline{v} := 0$ and $\overline{v} := v(1)$. Finally, in Case (iii) define $\underline{v} := v(\underline{s})$ and $\overline{v} := v(1)$. For any $v \in [\underline{v}, \overline{v}]$ the solution $s^*(v) = s^*$ satisfies

$$v = \frac{1}{2}\alpha_F d^2 (s^*)^2 \Delta_X^2 + \alpha_E (1-d)^2 s^* (1-s^*) \Delta_X^2. \tag{16}$$

Solving (16) for s^* we obtain

$$s^* = \frac{\alpha_E (1-d)^2 \Delta_X - \Phi}{\left(2\alpha_E (1-d)^2 - \alpha_F d^2\right) \Delta_X}, \tag{17}$$

where $\Phi := \sqrt{\alpha_E^2 (1-d)^4 \Delta_X^2 - 2v(2\alpha_E (1-d)^2 - \alpha_F d^2)}$. Clearly, s^* is strictly increasing in v. Inserting (17) in (15) yields the Pareto frontier $\psi(v)$. Differentiating $\psi(v)$ twice with respect to v we have

$$\frac{d^2\psi(v)}{dv^2} = -\Phi^{-3}\left[\left(\alpha_E (1-d)^2 - \alpha_F d^2\right)^2 + \alpha_E (1-d)^2 \alpha_F d^2\right] < 0.$$

To show that the sum of utilities $v + \psi(v)$ has a unique maximum in the interior of $[\underline{v}, \overline{v}]$ we compute the derivative of $\psi(v)$ at the boundaries. In Case (i) we have $\psi'(\underline{v}) = [\alpha_F d^2 - \alpha_E (1-d)^2]/[\alpha_E (1-d)^2] > -1$ and $\lim_{v \to \overline{v}} \psi'(v) = -\infty$. In Case (ii) we have $\psi'(\underline{v}) = 0$ and $\lim_{v \to \overline{v}} \psi'(v) = -\infty$. Finally, in Case (iii) we have $\psi'(\underline{v}) = 0$ and $\psi'(\overline{v}) = -\alpha_F d^2/[\alpha_F d^2 - \alpha_E (1-d)^2] < -1$. Since $\psi(v)$ is strictly concave this implies that in each case there exists a unique value $\hat{v} \in (\underline{v}, \overline{v})$ at which $\psi'(\hat{v}) = -1$. Q.E.D.

Cobb-Douglas Technology. Effort costs are assumed to be the same as above. To ensure that the equilibrium success probability has an interior solution we assume again that $\max\{\alpha_E (1-d), \alpha_F d\} < 1/\Delta_X$. Equilibrium effort choices are then given by

$$e^*(s) = (\alpha_E (1-d)(1-s) \Delta_X [a^*(s)]^d)^{\frac{1}{1+d}},$$

and

$$a^*(s) = (\alpha_F d s \Delta_X [e^*(s)]^{1-d})^{\frac{1}{2-d}},$$

implying that

$$p^*(s) = \rho(s) \Delta_X,$$

where $\rho(s) := [\alpha_F d s]^d [\alpha_E (1-d)(1-s)]^{1-d}$. The venture capitalist's and the entrepreneur's utility under the allocation s is

$$v(s) = \frac{1}{2}(2-d) s \Delta_X^2 \rho(s), \tag{18}$$

and

$$u(s) = \frac{1}{2}(1+d)(1-s)\Delta_X^2 \rho(s). \tag{19}$$

respectively.

From (18) and (19) it follows again that $v(s)$ and $u(s)$ are both quasiconcave, implying that s^* solves the entrepreneur's problem for some v if and only if $v(s)$ is nondecreasing and $u(s)$ is nonincreasing at s^*. Differentiating (18) with respect to s we have that $v(s)$ is nondecreasing if and only if $s \leq [1+d]/2$. Similarly, differentiating (19) with respect to s we have that $u(s)$ is nonincreasing if and only if $s \geq d/2$. Accordingly, the set of Pareto-optimal allocations is $[d/2, [1+d]/2]$, implying that $\underline{v} := v(d/2)$ and $\overline{v} := v([1+d]/2)$. Moreover, $v(s)$ is strictly increasing for all $s < [1+d]/2$, implying that $s^*(v) = s^*$ is strictly increasing for all $v < \overline{v}$. We next show that ψ is strictly concave. Differentiating $u(s)$ and $v(s)$ twice we obtain

$$\frac{d^2\psi(v)}{dv^2} = -\frac{1}{2}(1+d)\Delta_X^2 \rho s^* \left(\frac{1}{v'(s^*)}\right)^2 \left(\frac{d}{(s^*)^2} + \frac{(1-d)(2s^*-d)}{s^*(1-s^*)(1+d-2s^*)}\right),$$

which is strictly negative for all $s^* \in [d/2, (1+d)/2]$. To show that the sum of utilities $v + \psi(v)$ attains its maximum in the interior of $[\underline{v}, \overline{v}]$ we compute the derivative of $\psi(v)$ at the boundaries. The derivative of $\psi(v)$ is

$$\frac{d\psi(v)}{dv} = -\frac{(1+d)(2s^*-d)(1-s^*)}{s^*(2-d)(1+d-2s^*)}. \tag{20}$$

Evaluating (20) at $\underline{v}$ and $\overline{v}$ we obtain $\psi'(\underline{v}) = 0$ and $\lim_{v \to \overline{v}} \psi'(v) = -\infty$. Since $\psi(v)$ is strictly concave this implies there exists a unique value $\hat{v} \in (\underline{v}, \overline{v})$ such that $\psi'(\hat{v}) = -1$. Q.E.D.

7.2 Appendix B: Proofs

Proof of Proposition 1. To work with the first-order condition (3) we first need to show that the bargaining outcome lies in the interior of the domain of Ψ. Since $V^R \geq 0$ and $U^R \geq 0$, there are only two possible cases where this might not hold: (i) if $\underline{v} - I - \overline{w} > 0$ and $\Psi'(\underline{v} - I - \overline{w}) < 0$, and (ii) if $\Psi'(\overline{v} + X_l - I) > 0$ and $\lim_{V \to \overline{v} + X_l - I} \Psi'(V) > -\infty$. To show that these cases cannot arise we argue to a contradiction. Consider (i) first. As in Appendix A we denote the optimal allocation of the risky claim corresponding to a given value v by $s^*(v)$. By $\underline{v} - I - \overline{w} > 0$ we have $s^*(\underline{v}) > 0$. But $\psi'(v) = u'(s^*)/v'(s^*)$, $\psi'(\underline{v}) < 0$, and Pareto optimality imply that $u'(s^*(\underline{v})) < 0$. Hence there exists some allocation $s < s^*(\underline{v})$ which makes the entrepreneur better off, contradicting the construction of Ψ, which requires that $u(s)$ is maximized at $s^*(\underline{v})$. An analogous argument holds for (ii).

We next prove uniqueness. Inserting (4) to (5) into (3) yields (8). From the uniqueness of the bargaining solution it follows that (8) has a unique solution (U^B, V^B), where $V^B \in (0, \overline{v}+X_l-I)$. We analyze next how this solution is affected by a shift in θ. Implicitly differentiating (8) with respect to θ gives

$$\frac{dV^B}{d\theta} = \beta \frac{[r+q_F]\, q_E' - [r+q_E]\, q_F'}{[r+q_E]^2} \frac{\Psi^2}{\Psi\left[\Psi' + V^B \Psi''\right] - V^B \left(\Psi'\right)^2} < 0, \tag{21}$$

implying that $dU^B/d\theta > 0$. This, in conjunction with the monotonicity of q_E and q_F, implies that V^R is decreasing in θ and U^R is increasing in θ.

The claims made in connection with Cases I and II now follow immediately from (21) and the construction of the bargaining frontier. Note, in particular, that by (8) and the limit properties of q_F and q_E for $\theta \to 0$ and $\theta \to \infty$ we can indeed trace out the entire bargaining frontier. Q.E.D.

Proof of Proposition 4. In equilibrium, θ, U^B, and V^B are determined by (8) and the zero-profit constraint $V^R = k$. The total derivatives from these two equations generate the following equation system:

$$\begin{pmatrix} -\beta \frac{[r+q_F]q_E' - [r+q_E]q_F'}{[r+q_E]^2} & \frac{\Psi\left[\Psi' V^B \Psi''\right] - V^B (\Psi')^2}{\Psi^2} \\ V^B \frac{r q_F'}{[q_F+r]^2} & \frac{q_F}{q_F+r} \end{pmatrix} \begin{pmatrix} d\theta \\ dV^B \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \end{pmatrix} dk. \tag{22}$$

The determinant of this system, D, is negative. In conjunction with the limit properties of q_F and q_E for $\theta \to 0$ and $\theta \to \infty$ this establishes the existence and uniqueness of a solution to the equation system given by (8) and $V^R = k$. We can now apply Cramer's rule to find that

$$\frac{d\theta}{dk} = -\frac{1}{D}\left[-V^B \frac{r q_F'}{[q_F+r]^2} \frac{\Psi\left[\Psi' + V^B \Psi''\right] - V^B \left(\Psi'\right)^2}{\Psi^2}\right] < 0.$$

The rest follows from Proposition 1. Q.E.D.

Proof of Proposition 5. Define $\omega_1 := (r + \xi\theta^{-\frac{1}{2}})/(r + \xi\theta^{\frac{1}{2}})$ and $\omega_2 := \xi\theta^{-\frac{1}{2}}/(r + \xi\theta^{-\frac{1}{2}})$. Note that $d\omega_2/d\xi > 0$, $d\omega_1/d\xi < 0$ if $\theta > 1$, and $d\omega_1/d\xi > 0$ if $\theta < 1$. From the equation system generated by the total derivatives of (8) and $V^R = k$, we have that

$$\frac{dV^B}{d\xi} = \frac{1}{D}\left[\omega_2' V^B \beta \frac{[r+q_F]\, q_E' - [r+q_E]\, q_F'}{[r+q_E]^2} + \omega_1' \beta V^B \frac{r q_F'}{[q_F+r]^2}\right],$$

which is strictly negative if $\theta > 1$. The claims regarding the net surplus, riskiness of financial claims, market values, and success probability follow then immediately from the fact that we move along the bargaining frontier counterclockwise.

It remains to prove that we can indeed obtain $\theta > 1$ by choosing k sufficiently small. Suppose not. There then exists a sequence of equilibria indexed by n such that $\theta_n \to \overline{\theta}$ as $k_n \to 0$, where the limit $\overline{\theta}$ is finite. By (8) this implies that V_n^B converges to some strictly positive value $\overline{V}^B$. Since $\theta_n \to \overline{\theta}$, and since r is a constant, this contradicts the zero-profit constraint $V^R = k$ for large n. Q.E.D.

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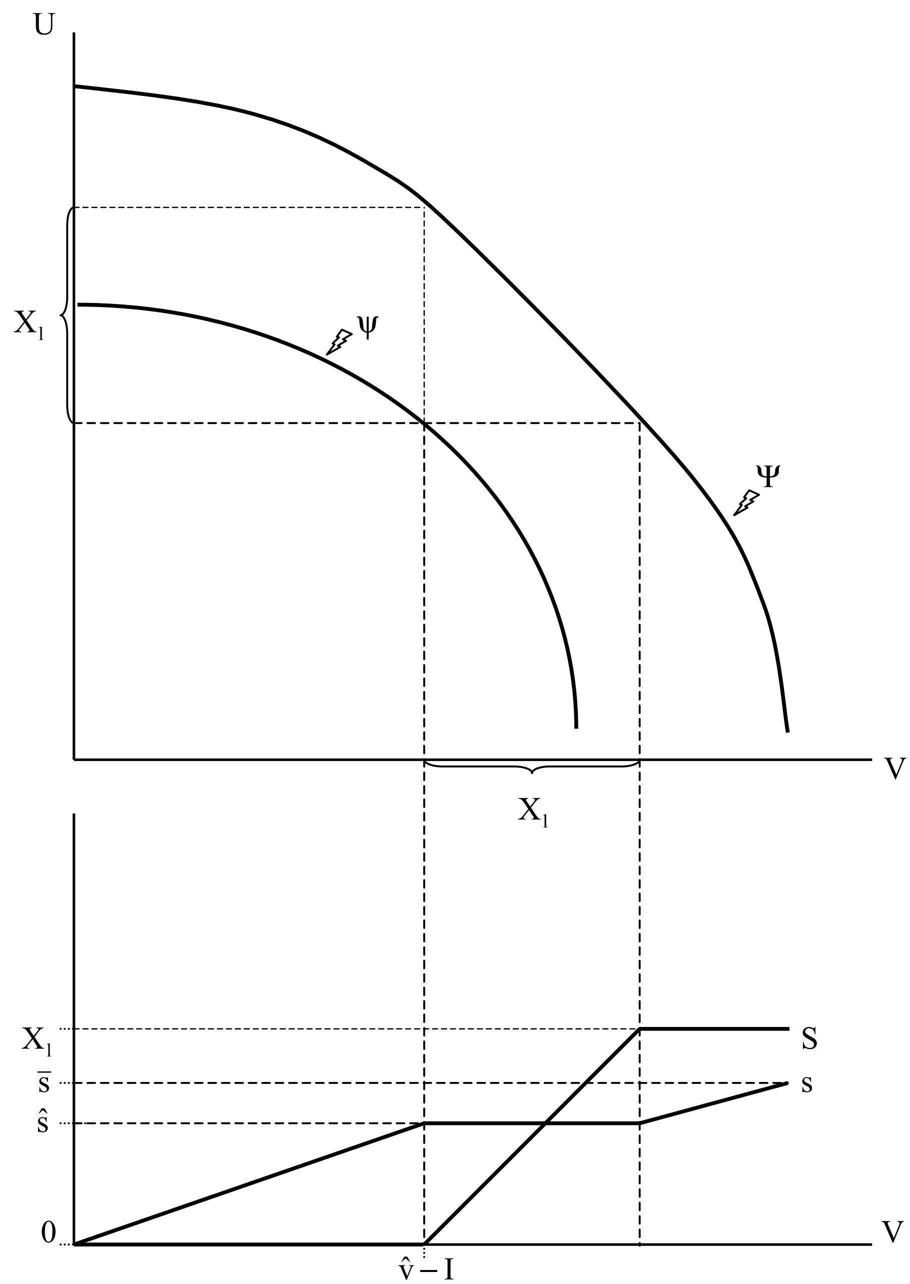

Figure 1a: Bargaining frontier for $\overline{w} = 0$. The graph of ψ characterizing the set of Pareto-optimal u-v combinations is adopted from the linear technology, Case (i), as discussed in Appendix A. The domain of ψ is $[0, \overline{v}]$, where $\overline{v} := v(\overline{s})$, and where the set of Pareto-optimal allocations of the risky claim is $[0, \overline{s}]$, with $\overline{s} < 1$: Since the entrepreneur is more productive, it is never optimal to give the venture capitalist the entire risky claim. Consequently, the entrepreneur's minimum utility under ψ is strictly positive. (Hence the gap as ψ approaches the X-axis.)

The domain of the bargaining frontier Ψ is as defined in Lemma 1.

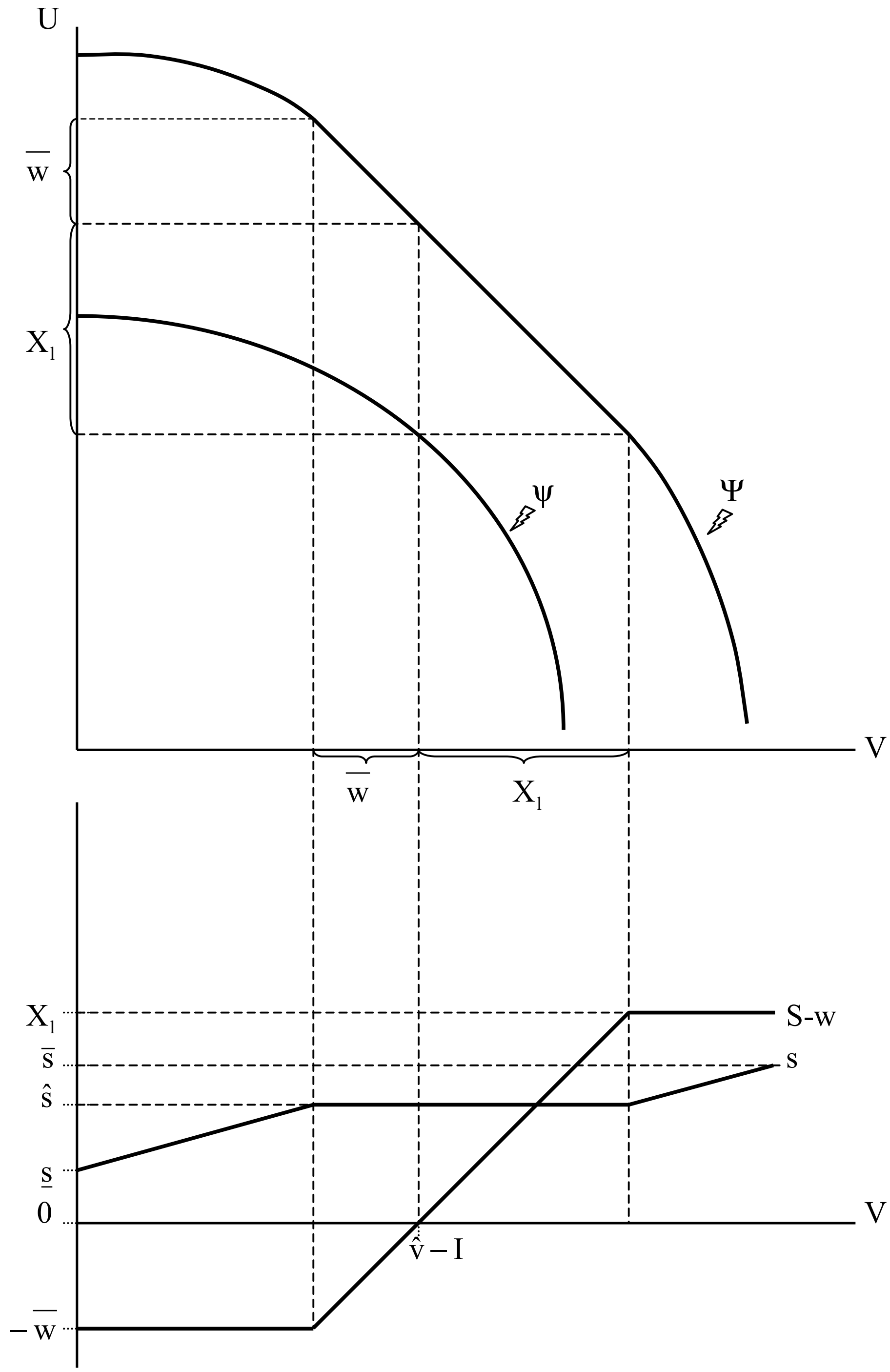

Figure 1b: Bargaining frontier for $0 < \overline{w} < \hat{v} - I$. Under the bargaining frontier Ψ the venture capitalist's share of the risky claim is bounded from below by $\underline{s} > 0$. Since in the left interval $S - w < 0$, the venture capitalist must hold a strictly positive fraction of the risky claim, or else his overall utility V becomes negative.
The safe claim and the wage payment are perfect substitutes. One solution is to use the safe claim for all $V > \hat{v} - I$ and to use the wage for all $V < \hat{v} - I$ to transfer utility.

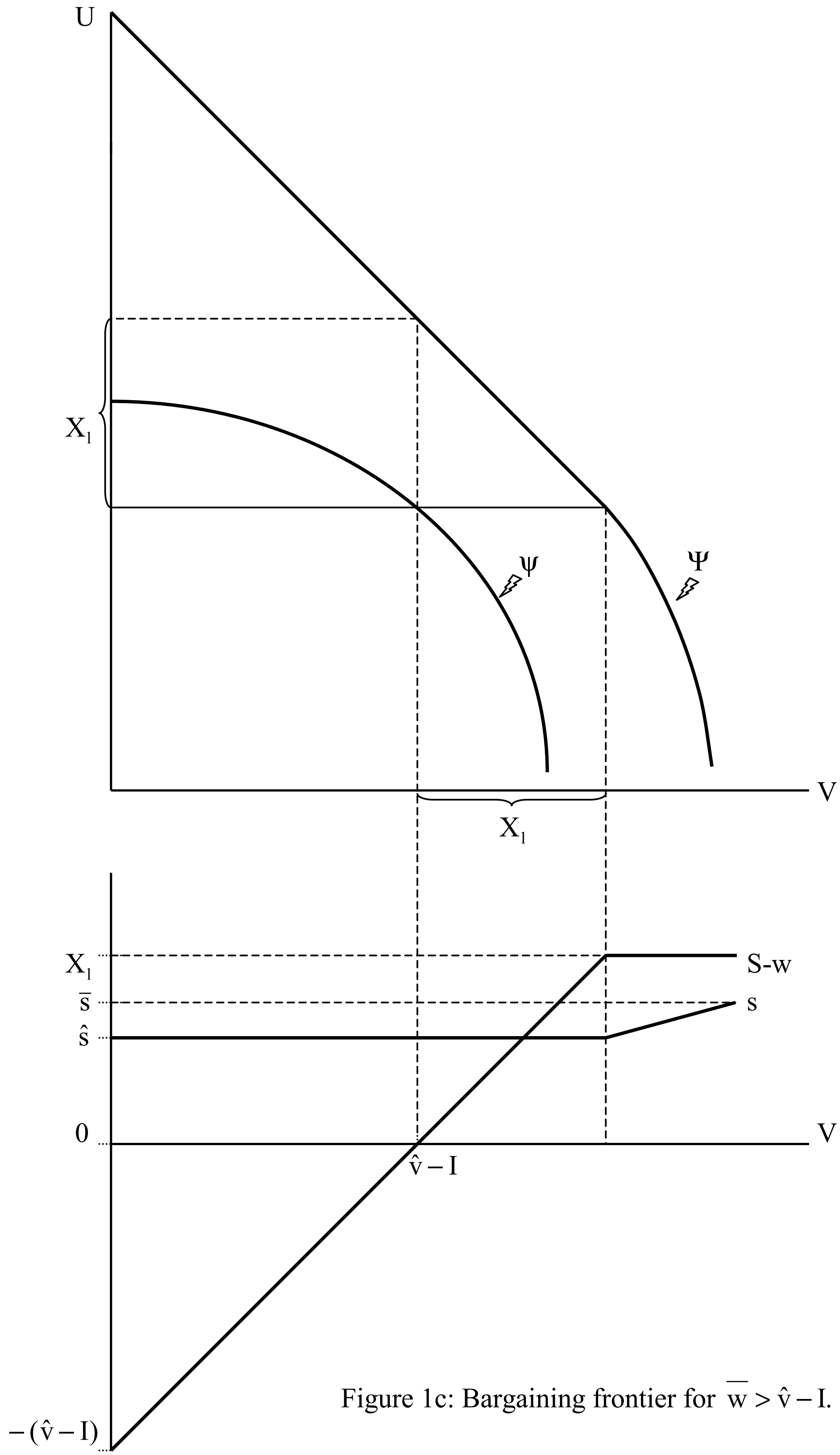

Figure 1c: Bargaining frontier for $\overline{w} > \hat{v} - I$.