Information and Control in Ventures & Alliances

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Abstract

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abstract

This paper develops a theory of control as a signal of congruence of objectives, and applies it to financial contracting between an investor and a privately informed entrepreneur. We show that formal investor control is (i) increasing in the information asymmetries ex ante, (ii) increasing in the uncertainty surrounding the venture ex post, (iii) decreasing in the entrepreneur's resources, and (iv) increasing in the entrepreneur's incentive conflict. In contrast, real investor control — that is, actual investor interference — is decreasing in information asymmetries. Control rights are further such that control shifts to the investor in bad states of nature.

Should better-informed parties receive more control rights in ventures or alliances? Recent research by Kaplan and Strömberg (2004) indicates that venture capitalists face substantial uncertainty when financing new ventures. Uncertainty and asymmetric information on behalf of the entrepreneur, however, are shown to be significantly correlated with less entrepreneur control, not more. Standard theories of control rights in financial contracting such as Aghion and Bolton (1992) offer little insight into these findings as they neglect asymmetric information. Agency theories that do consider the link between asymmetric information and control, on the other hand, argue that better-informed parties should receive more control in order to avoid information distortion (Dessein (2002)) or to provide better incentives for information acquisition (Aghion and Tirole (1997)). They thus predict an opposite relationship.

This paper argues that a privately informed "entrepreneur" relinquishes control to an "investor" in order to signal the congruence of their preferences. Consistent with empirical findings, this theory implies that controlling for observable quality, investor control is increasing in both the ex ante asymmetric information of the entrepreneur and the uncertainty the investor faces during the course of the venture. Control rights should further be contingent on verifiable measures of performance, with control shifting to the investor in bad states of nature.

Key in our model is that the entrepreneur does not care about *formal control* rights per se; he derives private benefits only from having *real control*, that is, from the venture undertaking certain actions.[2] Hence, the entrepreneur has not much to lose by giving up formal control to an investor with similar preferences. If preferences are dissonant, in contrast, he may refrain from this out of fear of interference by the investor. In our model, the entrepreneur cares about a particular project being carried out, whereas the investor cares about revenues. Preferences are congruent if the entrepreneur's project is likely to yield high revenues.

Concretely, we assume that during the course of the venture, the investor receives (noisy) information about the profitability of the project. Offering control rights to the investor makes the future of the venture contingent on this ex post information. Whereas this is not very costly for a "good" (congruent) entrepreneur, who knows that the information is likely to be favorable, this may prevent a "bad" (dissonant) entrepreneur from seeking funding.

Exploring the distinction between formal and real control in financial contracting results in two apparent paradoxes. First, controlling for observable quality, the more favorable the private information of the entrepreneur, the more formal control rights he relinquishes. Second, we show that even if formal investor control increases, real investor control may diminish. Intuitively, if control is a signal of congruence, then the investor puts more trust in the entrepreneur upon receiving control. But if the investor trusts the entrepreneur, she has a tendency to leave the entrepreneur "in charge", even when she learns bad information about the latter's project. The better the entrepreneur is informed and, hence, the more favorable the information of a "good" type, the more the investor tends to neglect her own information. In order to avoid pooling by bad types, a good type then needs to give up more control rights to signal his congruence. A first testable prediction of our model is thus that investor control is increasing in level of asymmetric information. But, since the investor intervenes less, the entrepreneur's real control increases. In other words, in equilibrium, the entrepreneur trades formal control rights for real control.

A second testable prediction of our model is the impact of general (two-sided) uncertainty. Intuitively, more ex post uncertainty makes monitoring by the investor less effective. In particular, the investor then puts less faith in his own information and is thus less inclined to intervene. In order to distinguish himself from a bad type, a good type then needs to relinquish more control. In other words, controlling for observable quality, investor control is also increasing in the level of ex-post uncertainty.

Control is typically not an indivisible right held by either the investor or the entrepreneur, but resembles a continuous variable adjusted through contingent provisions.[3] In a first step, our model captures this by allowing for a probabilistic control allocation. Such an allocation becomes more relevant, however, once we allow for control to be made contingent on a measure of performance that is correlated with the investor's information. As we show, control then shifts to the investor after bad performance. When the entrepreneur is better informed, control shifts to the investor in more states of nature. Intuitively, a contingent control allocation improves upon a random control allocation, as it reduces intervention in precisely those states of nature where the investor is most likely to mistakenly intervene in a good project. Hence, it allows the probability of intervention faced by a good entrepreneur to decrease, while keeping the threat of intervention constant for a bad type.

The relation between information and control, as depicted above, is consistent with empirical findings on venture capital contracts and strategic alliances. Kaplan and Strömberg (2003), for example, find that VC's are more likely to have board and voting control in pre-revenue ventures and in industries with a higher volatility; in contrast, they are less likely to have voting control with repeat entrepreneurs (similar empirical findings are reported by Gompers (1998)).[4] As they argue: "These results indicate that when the uncertainty about the venture and the quality of the founder is higher, the VC is allocated more control" (page 302). Kaplan and Strömberg (2004) explicitly test our predictions using direct risk-assessments in VC investment memos. Such risk-assessments allow them to distinguish between internal risks — which relate to management actions and management quality and are thus more likely to be subject to asymmetric information — and external risks, about which the entrepreneur is unlikely to be better informed. Consistent with our predictions, both types of risk are significantly correlated with more investor control. Finally, analyzing 200 biotech alliances, Lerner and Merges (1998) find that projects in their early stages at the time of the alliance formation assign significantly less control to the R&D firm.[5] Intuitively, these are the stages where the uncertainty and the informational asymmetries between investor and entrepreneur are most extreme.

Broadly speaking, the literature has taken two approaches in explaining why control rights matter.[6] Following Grossman and Hart (1986), one strand has argued that decision rights may be important for influencing relation-specific investments. Control rights are then allocated in such a way as to minimize the under-investment of each party. As argued by Aghion and Tirole (1994), this goes in favor of allocating control to the entrepreneur, since the latter's investment is probably most difficult to specify contractually.[7] The financial contracting literature, instead, has focused on how control rights affect the trade-off between cash flows and private benefits. As shown by Aghion and Bolton (1992), control is again efficiently allocated to the entrepreneur, since the investor is a ruthless value-maximizer who neglects these private benefits. The only reason why we may observe investor control are financing constraints: Whereas entrepreneur control is efficient, it may not dispense enough verifiable profits to give the investor his required rate of return. Aghion and Bolton (1992) further show how contingent control rights are then often optimal.[8] While the impact of financing constraints on control seems to be supported by the data, the above theories cannot fully explain the impact of uncertainty and asymmetric information. The above papers have been complemented by a number of studies, including Berglof (1994), Cornelli and Yosha (2003), Hellman (1998, 2002), Gompers (1995), Kirilenko (2001), Casamatta (2003), and Schmidt (2003), which focus specifically on characteristics of venture capital contracts.

Starting with Leland and Pyle (1977), there is a large literature about signaling in financial contracts. Much of this literature argues that *low-risk debt* is a good way to signal the quality of one's project (following Myers and Majluf (1984)). However, in the situations we have in mind — start-ups, technology alliances — debt is typically as risky or information-sensitive as equity. Since the variance in the revenues tends to be very large relative to the required investment, debt is often not a viable alternative to signaling with control.[9]The signaling model that comes closest to ours is Diamond (1991), which provides a theory of *short-term versus long-term debt.* In this model, short-term debt is similar to investor control, as it gives the lender the option to either refinance the venture or liquidate it at an intermediate date. The borrower is further privately informed and may be good or bad. Unlike in our model, however, a good borrower never can use short-term debt to signal his type, as there is always pooling by "bad" borrowers. In Diamond, a good borrower may nevertheless prefer short-term debt over long-term debt, as the liquidation of bad projects reduces his financing cost.

The paper is organized as follows. Section I outlines the model. In Section II, I characterize the equilibrium allocation of control rights under symmetric and asymmetric information. Section III then discusses the determinants of investor control and relates these to the empirical evidence. In Section IV, I expand the contractual framework by allowing for contingent control rights. Section 5 provides two alternative interpretations of our model. First I show that the results carry through if the difference between a good and a bad project is not its quality, but whether or not the returns are transferable. This supports the claim that control rights are a signal of congruence, not simply quality. Second, we show how investor control can be implemented by issuing short-term debt. In particular, the investor then can gain control over the venture by refusing to refinance it. Section VI concludes.

I. The Model

Consider a young technology firm that has a novel idea, but lacks financial means or complementary assets and, hence, must rely on an alliance with a venture capitalist or a large corporation to implement its project. To set up the project, the technology firm, referred to as the *entrepreneur (he)*, and the corporation or venture capitalist, referred to as the *investor (she),* must both commit some critical resources, whose opportunity cost we denote respectively by K and I.[10] Besides K, our entrepreneur has no wealth. We assume that there is more than one investor interested in the project, so that the entrepreneur has all the bargaining power and can make a take-it-or-leave-it offer to the investor. There are three dates. At date 0, the entrepreneur proposes a contract and the investor accepts if it promises an expected return of at least I. At date 1, an action $a \in A$ must be taken that affects the nature and returns of the project. At date 2, the returns of the project are realized.

Preferences. — Both the investor and the entrepreneur are risk neutral in income. The entrepreneur, however, also derives non-verifiable returns or *private benefits* from some actions. First of all, he may care about less tangible things such as reputation, specific human capital, effort, and on-the-job consumption. Second, in *technology alliances*, part of the output of the project is often consumed internally and is thus unverifiable. In addition, the project may have (positive or negative) externalities on other projects/products. The research carried out, for example, may be useful for projects that do not belong in the scope of the joint venture.[11] For simplicity, we assume that there are only two relevant actions at date 1 : a_o (private benefit action) and a_R (restructuring action).

(i) We denote by a_o the action which preserves the *original nature of the project*. Since it was the entrepreneur who thought about the project and took the initiative of setting it up, and since a_o probably requires that the entrepreneur runs the project, we assume that a_o yields a private benefit to the entrepreneur, whose monetary equivalent we denote by Z. The impact of a_o on the verifiable monetary returns of the project is stochastic. With a probability α, the project provides a verifiable return at date 2 which is normalized to 1. With a probability

$1 - \alpha$, the project will fail (and have no verifiable profits). The expected revenues of a_o thus equal α.[12]

(ii) Alternatively, the project can be *re-structured* or *re-organized* at date 1, an action which is denoted by a_R. We assume that a_R is less risky than a_o : a_R yields a lower return $v < 1$, but one realized in both states. This reflects the fact that a reorganization typically involves (at least) partial sales of assets or reduction of activities.[13] Given that a_R totally changes the nature of the project and typically implies that the entrepreneur stops running the project, it destroys all private benefits of the entrepreneur. We further assume that a_R does not allow the investor to recoup her investment; that is, $v < I$.

INSERT TABLE 1 HERE

To focus on asymmetric information and adverse selection as a driver of control rights, we impose the following parameter restrictions:

- In every state of the world, the entrepreneur derives a net utility of the project going ahead: $Z > K$ **(A1)**
- Entrepreneur control is feasible under symmetric information: $\alpha > I > v$ **(A2)**
- In every state of the world, a_R is weakly inefficient: $Z \geq v$ **(A3)**

Assumption A1 implies that the entrepreneur always wants to obtain financing for the project, even if he knows it will fail. Assumption $A2$ implies that under symmetric information, the project yields enough cash-flow in expectations to give the investor her required rate of return. Hence, the entrepreneur does not need to give up control in order to provide the investor with more verifiable returns as in Aghion and Bolton (1992). Assumption $A2$ thus distinguishes the rationale for investor control in our model from the one developed by Aghion and Bolton (1992) and works against our main results (investor control in equilibrium). Assumption $A3$ is a simplifying assumption which pushes in the direction of entrepreneur control (and thus also works against our main results): Whereas the investor may be willing to restructure the project if she is sufficiently pessimistic about its prospects, the entrepreneur always prefers to keep the project going "as is".

Information Structure. — The entrepreneur is privately informed about the profitability of the project: If the project is a lemon, then with positive probability this is revealed to the entrepreneur. We denote by $\alpha_g > \alpha$ the *probability of success when the entrepreneur receives no bad signal.* We refer to the latter as a "good" type and to the former as a "bad" type. There is a direct relationship between how favorable the information is for good types and the asymmetric information of the entrepreneur. If $\alpha_g = 1$, the entrepreneur is perfectly informed, whereas if $\alpha_g = \alpha$, he has no informational advantage over the investor. Indeed, $\alpha_g = \alpha$ implies that the entrepreneur never receives a bad signal.[14]Hence, $\alpha_g - \alpha$ is a *measure of the asymmetric information* between investor and entrepreneur.

As the project proceeds, more information becomes available. In particular, between date 0 and date 1, a non-verifiable public signal t is revealed, which is distributed according to $F_g(t)$ if the project will be a success, and according to $F_b(t)$ if the project will fail. A good entrepreneur thus knows that t is drawn from $F_g(t)$ with probability α_g, and from $F_b(t)$ with probability $1 - \alpha_g$. We assume that both $F_b(t)$ and $F_g(t)$ have full support on $[-\infty, +\infty]$, and that high values of t are more likely if the project will be successful; that is, the distribution of t satisfies the monotone likelihood ratio property: $\zeta(t) \equiv f_g(t)/f_b(t)$ is increasing in t.

Note that the presence of two-sided asymmetric information, where the investor also possesses private information, is not incompatible with our model. In contrast to a bad entrepreneur, an investor who receives unfavorable information ex ante would simply not be interested in financing the venture. Indeed, due to the absence of private benefits, there is no adverse selection on behalf of the investor. In this sense, α can be interpreted as the probability the investor assigns to a good outcome after having successfully screened the project. Hence, for our results to hold, it is only required that the entrepreneur possesses some private information, not that he be better informed than the investor.[15]

INSERT FIGURE 1 HERE

Contracts and Control. — At date 0, the entrepreneur proposes a contract to the investor.[16] Actions are non-contractible, except for who has the authority over them.[17] Given that the revenues of the project are verifiable, the standard incentives schemes considered in the Principal-

Agent literature are feasible subject to the constraint that the entrepreneur's wealth cannot be negative. The set of ex ante contracts includes all contracts specifying:

(i) A cash-flow claim W for the investor in case $r = 1$. There are three possible outcomes for the final period returns: $r \in \{1, v, 0\}$. Since the entrepreneur is wealth constrained, the contract needs only to specify a compensation $W \leq 1$ in case $r = 1$ and a compensation $w \leq v$ in case $r = v$. To focus on control rights rather than cash-flow claims, however, we make the simplifying assumption that $w = v$ exogenously. In other words, the investor receives all the revenues in case of intervention. For example, if the investor has control over the venture but is pessimistic concerning its future, then she may reorient the venture's project to foster her own private goals, raid the assets of the venture, or a combination of both. In the latter case, v denotes the unverifiable profits or benefits of such actions to the investor. Even if the restructuring revenues v are verifiable, it is an empirical regularity in venture capital contracts that the investor receives all of the revenues if the latter are low.(Kaplan and Strömberg (2003)). While this could be for unmodeled reasons – for example, to induce more effort on behalf of the entrepreneur — a previous version of this paper shows that $w = v$ typically arises endogenously in our model.

(ii) A control allocation. We denote by $\gamma \in [0, 1]$ the probability that the investor receives control over the date 1 action. Control is typically not an indivisible right held by either the investor or the entrepreneur, but resembles a continuous variable adjusted through contingent provisions (Lerner and Merges (1998), Gompers (1998), Kaplan and Strömberg (2003)). A probabilistic control allocation allows us to capture this in a very parsimonious, albeit imperfect, way. In section IV.A, we allow for *contingent control rights* where γ can be made contingent on a measure of performance that is correlated with t.

We denote a particular contract by $c = (\gamma, W)$. In the absence of renegotiation, the action taken at date 1 will be determined by the returns of the controlling party. Because this choice may be inefficient, parties may have an incentive to renegotiate the initial contract. In particular, once t has been learned, the entrepreneur can make a take-it-or-leave-it offer of a new contract to the investor. As we show in Section II.A, such a renegotiation involves the investor receiving a higher cash-flow claim.

Equilibrium selection. — The fact that the entrepreneur is privately informed about the state of nature turns the contract offering into a signaling game, and it is well known that such games are plagued by multiple equilibria. As is standard in signaling models, we will focus on the Perfect Bayesian Nash equilibria that survive the Intuitive Criterion, the refinement proposed by Cho and Kreps (1987), and refer to them as CK-equilibria.

II. Control as a Signal of Congruence

Control rights in a venture are irrelevant if the preferences of the investor and entrepreneur are perfectly congruent. This suggests that an asymmetrically informed entrepreneur may use control rights to signal favorable private information: To the extent that the entrepreneur is confident that his project will be a success — and also the investor will prefer a_o over a_R — he has not much to lose by giving up control to the investor. This section characterizes investor behavior and the equilibrium contracts under symmetric and asymmetric information. Section III then characterizes the determinants of investor control.

A. Investor Behavior and Break-even Constraint

We first characterize the behavior of an investor who has accepted a contract c at date 0. What are the incentives of the investor to intervene in equilibrium? Let β_0 be the *investor's belief that the project will be a success upon being offered contract c at date* 0. We have

$$\beta_0 \equiv \beta_0(c) \in [0, \alpha_g] . \tag{1}$$

During the course of the venture, the investor receives a signal t and updates β_0 using Bayes' rules. Denoting by β_1 this *updated date* 1 *belief*, we have that

$$\beta_1 \equiv \beta_1(t, \beta_0) = \frac{\beta_0 \zeta(t)}{\beta_0 \zeta(t) + (1 - \beta_0)}. \tag{2}$$

Note that upon observing t, a good type knows that his project will succeed with a probability $\beta_1(t, \alpha_g)$. A bad type knows that his project will fail.

In the absence of renegotiation, the investor intervenes if and only if $\beta_1 * W < v$. As long as $\beta_1 > v$, however, the entrepreneur can offer the investor a larger cash-flow right, $W' = v/\beta_1$, in which case the investor prefers to leave effective control to the entrepreneur (action a_o).[18] Allowing for renegotiation, an investor with control thus intervenes if and only if

$$\beta_1(t, \beta_0) < v. \tag{3}$$

From (2) and the MLRP, $\beta_1(t, \beta_0)$ is increasing in t. This yields the following lemma:

lemma 1: (i) Given β_0, there exists a cut-off value $\hat{t} \equiv \hat{t}(\beta_0)$ such that the investor intervenes if and only if $t < \hat{t}(\beta_0)$.
(ii) $\hat{t}(\beta_0)$ is decreasing in β_0, and given by $\zeta(\hat{t}(\beta_0)) = \dfrac{v}{1-v}\dfrac{1-\beta_0}{\beta_0}$.[19]

In the remainder of the paper, we will refer to *real investor control* as to the probability that the investor actually interferes in the venture. We will refer to *formal investor control* as the probability γ that the investor has the right to intervene. From lemma 1, keeping γ fixed, real investor control is decreasing in the initial confidence of the investor. Indeed, $\hat{t}(\beta_0)$ is decreasing in β_0 and the lower is $\hat{t}(\beta_0)$, the less likely it is that the investor will want to intervene in the venture. Intuitively, as the investor has more trust in the entrepreneur, she is more willing to neglect unfavorable information and leave the entrepreneur in charge. The distinction between real and formal investor control will play a crucial role in our analysis.

The investor's break-even constraint: At date 0, the investor accepts the contract if and only if W, γ and $\beta_0(c)$ are sufficiently high such that she breaks even in expectations. Since a bad type's project never generates any cash-flow, a bad type is willing to mimic any cash-flow claim offered by a good type. Hence, a good type can never use W to signal his type. Since W may be renegotiated to $W' = v/\beta_1$ at date 1, what matters for the expected utility of a good type is not the W offered at date 0, but the average cash-flow claim paid out at date 2 in case of success. Denoting by $\bar{W}$ the *average investor cash-flow claim conditional on the project being successful*, $\bar{W}$ is uniquely defined by

$$I = \beta_0(1 - \gamma F_g(\hat{t}(\beta_0))\bar{W} + \gamma\left[\beta_0 F_g(\hat{t}(\beta_0) + (1-\beta_0)F_b(\hat{t}(\beta_0)\right]v. \tag{4}$$

Using $\bar{W}$, the expected utility to a good type can be expressed as

$$EU_g = \alpha_g(1 - \gamma F_g(\hat{t}(\beta_0))\left[1 - \bar{W} + Z\right] + (1-\alpha_g)(1 - \gamma F_b(\hat{t}(\beta_0))Z - K, \tag{5}$$

and depends on formal investor control, investor beliefs, and the investor's cash-flow claim. The expected utility of a bad type, in contrast, is given by

$$EU_b = \left[1 - \gamma * F_b\left(\hat{t}(\beta_0)\right)\right] Z - K, \tag{6}$$

and is independent of the investor's cash-flow claim.

B. The Symmetric Information Benchmark

Under symmetric information, the entrepreneur never receives a bad signal such that $\alpha_g = \alpha$. Since contracts have no signaling value, $\beta_0(c) = \alpha$. It follows that under investor control, a successful project is mistakenly restructured with probability $\alpha F_g(\hat{t}(\alpha))$. In contrast, under entrepreneur control, a successful project is never restructured. Moreover, by assumption $A2$, entrepreneur control is also feasible. This yields the following control allocation:

proposition 1: Under symmetric information, the entrepreneur proposes a contract with full entrepreneur control and $W = I/\alpha$.

Note that the above result does not rely on assumption $A3$, which posits that intervention in bad projects is inefficient. Indeed, if v were to be larger than Z, renegotiation would ensure that under entrepreneur control, a project is restructured whenever this is ex post optimal given the realization of t. Investor control would again result in excessive intervention.

C. Control Allocations under Asymmetric Information

Consider now an entrepreneur who either knows that his project will fail (a bad type), or, in contrast, believes that his project will succeed with probability $\alpha_g > \alpha$ (a good type). We first look for the existence of a separating or semi-separating equilibrium in which a good entrepreneur offers a contract c specifying a stochastic control allocation γ and a cash-flow claim W. In any (semi-)separating equilibrium, a bad type must not strictly prefer to mimic a good type. This will be the case if and only if

$$\left[1 - \gamma * F_b\left(\hat{t}(\beta_0(c))\right)\right] * Z \leq K. \tag{7}$$

The right-hand side of (7) is the entrepreneur's stake in the venture. The left hand side equals the entrepreneur's private benefit of having real control over the venture, multiplied by the probability of being in control. Since a bad type's project never generates any cash-flow, a bad type is indifferent to mimic any cash-flow claim offered by a good type, from which (7) is independent of W.

It is important to note that a bad type's real control is not only increasing in his formal control, $1-\gamma$, but also in the initial confidence of the investor, $\beta_0(c)$. It will be useful to define β^s as the *belief* β_0 *for which* (7) *holds at the equality given full investor control*:

$$1 - F_b\left(\hat{t}(\beta^s)\right) \equiv K/Z. \tag{8}$$

In any separating equilibrium, (7) must be satisfied given $\beta_0(c) = \alpha_g$. Since $F_b(\hat{t}(\beta_0))$ is decreasing in β_0, the following results stem directly from (7) and (8):

lemma 2: Equilibrium investor beliefs about project quality induced by a contract c, $\beta_0(c)$, *can never be more favorable than* $\max\{\beta^s, \alpha\}$.

proposition 2: No separating equilibrium exists if $\alpha_g > \beta^s$.

From proposition 2, if a good type has very favorable information about his project, then he cannot perfectly reveal this information by simply relinquishing formal control to the investor. Intuitively, if giving up control were to truthfully reveal the entrepreneur's type, the investor would have a nearly blind belief in the entrepreneur, and she would almost never make use of these control rights. Indeed, from Lemma 1, as α_g goes to 1, the *real control* of a good type in a separating equilibrium becomes complete. But giving up formal control rights is then such a small sacrifice for a bad entrepreneur that pooling becomes unavoidable.

Note that there is a direct relationship between how favorable the information is for a good type and the asymmetric information of the entrepreneur. Indeed, if one keeps the average quality of a project constant, but increases the variance in project quality among good and bad types, then the average project quality of a good type must increase.

For our purpose, it will be useful to define the following thresholds for the ratio K/Z:

$$\delta^H \equiv 1 - F_b\left(\hat{t}(\alpha_g)\right), \tag{9}$$

$$\delta^L \equiv 1 - F_b\left(\hat{t}(\alpha)\right) < \delta^H. \tag{10}$$

The next proposition characterizes all equilibria which are not pareto-dominated. Figure 2 illustrates these equilibria as a function of the ratio K/Z and the asymmetric information, α_g.

proposition 3: i) If $K/Z \geq \delta^H$*, there exists a unique, separating, CK-equilibrium in which a good type offers a contract* c^* *specifying date 1 investor control* γ^* *given by*

$$1 - \gamma^* F_b\left(\hat{t}(\alpha_g)\right) = K/Z, \tag{11}$$

and a cash-flow claim W *such that the investor breaks even in expectations.*

ii) If $K/Z < \delta^H$ *:*

- For $K/Z \in \left(\delta^L, \delta^H\right)$*, there exists a semi-separating CK-equilibrium in which a good type proposes a contract* c^* *specifying* $\gamma = 1$ *and a bad type pools with a probability* q^* *such that*

$$\beta_0(c^*) = \beta^s \Leftrightarrow \frac{\alpha\alpha_g}{\alpha + (\alpha_g - \alpha)q^*} = \beta^s. \tag{12}$$

- There exists a continuum of CK pooling equilibria in which both a good and a bad type propose a contract c^* *specifying* $\gamma \in [\gamma^p, \gamma']$ *where* $\gamma^p > 0$ *and* $\gamma' = 1 \Leftrightarrow K/Z \leq \delta^L$.

proof: See Appendix ■

INSERT FIGURE 2 HERE

From Proposition 3, a separating equilibrium exists if and only if the ratio K/Z is larger than some threshold δ^H, where δ^H depends on the ex ante asymmetric information of the entrepreneur and the ex post uncertainty faced by the investor. Intuitively, it is more difficult to prevent a bad type from seeking financing if the latter has not much to lose, that is if his stake K in the venture is small, or his private benefits of control Z are large. Only if K/Z is large enough, intervention is sufficiently costly to the entrepreneur to sustain a separating equilibrium. Note that if K were to be larger than Z — in violation of assumption $A1$ — there always would exist a separating equilibrium with full entrepreneur control. Indeed, no signalling is necessary then, as a bad type prefers not to seek financing.

Even though a good type is more likely to preserve real control in a separating equilibrium, as the interim information t is more likely to be favorable for him, he still faces intervention with positive probability. Indeed, since the project of a good type fails with probability $1 - \alpha_g$, the investor intervenes whenever she observes a low realization of t. Since the interim signal t is noisy, however, the investor often mistakenly intervenes in a successful project. A good type prefers, therefore, to minimize investor control subject to the incentive constraint of a bad type. This minimum level of investor control is given by (11). As usual, this least-cost separating equilibrium, if it exists, is the unique equilibrium that satisfies the Cho-Kreps Intuitive Criterion.[20]

As hinted by Proposition 3, the threshold δ^H depends on the asymmetric information of the entrepreneur. The reason is that real investor control in a separating equilibrium is decreasing in α_g, the ex ante probability that a good type's project will be successful. Whenever $\alpha_g > \beta^s$, this real investor control is too small to prevent a bad type from seeking financing, and full separation is not feasible. Indeed, from (8) and (9),

$$K/Z > \delta^H \Longleftrightarrow \alpha_g < \beta^s. \tag{13}$$

Now, consider $K/Z < \delta^H$. If there exists a positive probability q that a bad type also relinquishes control, the investor will be less trusting and intervene more often. Concretely, given that a good type offers a contract c^* specifying full investor control, then (7) will be satisfied whenever a bad type pools with a probability $q \geq q^*$, where q^* is such that the investor's beliefs upon receiving c^* equal β^s. If $\beta^s > \alpha$, which is the case whenever $K/Z > \delta_L$, then there exists a semi-separating equilibrium in which a good type always offers full investor control ($\gamma = 1$) and a bad type mimics the good type with probability $q^* < 1$.[21] In Appendix, we show that all semi-separating equilibria in which the entrepreneur relinquishes control with a probability $\gamma < 1$ are pareto-dominated by the above equilibrium, as they involve more pooling by bad types.

For $K/Z < \delta^H$, pooling equilibria coexist next to the above semi-separating equilibrium or, for $K/Z < \delta_L$, are the only equilibria. In the Appendix, however, we show that as long as K/Z is close to δ^H, a good type is strictly better off in the semi-separating equilibrium with full investor control relative to any CK pooling equilibrium. Even as K/Z tends δ_L and, hence, there is almost complete pooling in the semi-separating equilibrium, we show a good type strictly prefers the latter equilibrium, provided that the fraction of bad types in the population is sufficiently large. Similarly, a good type then prefers the pooling equilibrium with $y = 1$ over the pooling equilibrium with $y = y^p$ for $K/Z < \delta_L$. As in Diamond (1991), the intuition is that even when control provides no signaling function, a good type might prefer to relinquish full control, since the liquidation of bad projects reduces his financing costs.

To conclude, it is interesting to compare Propositions 1 and 3. Whereas full entrepreneur control is the unique outcome under the symmetric information benchmark, even a small amount of asymmetric information induces the entrepreneur to relinquish (some) control rights to the investor. Indeed, even for $K/Z < \delta^L$, the pooling equilibrium in which the entrepreneur keeps full control never satisfies Cho and Kreps' Intuitive Criterion.[22]

III. Determinants of Investor Control

We are now ready to derive a number of comparative static results. Respectively, we analyze the impact of a change in the ex ante asymmetric information between investor and entrepreneur, a change in the ex post uncertainty, and finally, the impact of a change in the private benefits and the pledgeable resources of the entrepreneur. While we will focus on the parameter range for which a unique separating equilibrium exists, Section III.D discusses how these comparative statics generalize for $K/Z < \delta^H$. Tables II and III summarize our results.

INSERT TABLE 2 AND TABLE 3 HERE

A Ex ante Asymmetric Information

Consider first a change in the informational advantage of the entrepreneur, as characterized by $\alpha_g - \alpha$. Note that we only consider changes in asymmetric information, which leaves observable project quality, α, unaffected.

When the entrepreneur is better informed, the investor is more likely to trust an entrepreneur who has signaled favorable private information at the contracting stage. In particular, she is more inclined to neglect ambiguous information during the course of the venture. In terms of our model, the threshold below which the investor intervenes, $\hat{t}(\alpha_g)$, is decreasing in α_g. This decrease in real investor control, however, makes it less costly for a bad type to seek financing as well. In order to separate himself from a bad type, an entrepreneur who is confident of having a good project then needs to assign more formal control rights to the investor. Formally, in the separating equilibrium, investor control γ^* is such that a bad type is indifferent between seeking financing or not:

$$1 - \gamma^* * F_b\left(\hat{t}(\alpha_g)\right) = K/Z. \tag{14}$$

Since $\hat{t}(\alpha_g)$ is decreasing in α_g, the following result follows:

proposition 4: For $K/Z > \delta_H$, formal investor control, γ^*, is strictly increasing in α_g.

The above result stands in sharp contrast to *informational theories of authority and control in organizations.* In particular, agency theory has argued that control should be allocated to the better informed party in order to avoid information distortion (Dessein (2002)) or to provide better incentives for information acquisition (Aghion and Tirole (1997)). In contrast, this paper argues that the investor should receive more control as the entrepreneur becomes better informed. Similarly, in the next section, we show that the investor should receive more control as his ex post information becomes more noisy. In other words, investor control is increasing in the investor's informational disadvantage. The key difference between our theory and the above agency theories is that the latter consider a pre-defined authority relationship, where one party (the principal) has control, but may decide to transfer this control to a better informed agent. In the present paper, there is no such pre-defined relationship: The parties must still agree whether or not to enter into a relationship and on what terms. In the presence of asymmetric information, control may – and will – then be used by the better informed party as a signal of congruence and favorable information.

While an entrepreneur whose private information is more favorable assigns more *formal control rights* to the investor, this does not imply that he also faces more *real investor control* in equilibrium. Intuitively, it is precisely *because* the investor is less eager to interfere that she receives more formal control rights and thus more opportunities to interfere. Indeed, from Proposition 3, in a separating equilibrium, real investor control in a good project, $\gamma^* F_g(\hat{t}(\alpha_g)$, equals

$$(1 - K/Z)\frac{F_g(\hat{t}(\alpha_g))}{F_b(\hat{t}(\alpha_g))}. \tag{15}$$

Since the intervention threshold $\hat{t}(\alpha_g)$ is decreasing in α_g, and from the MLRP, $F_g(t)/F_b(t)$ is increasing in t, the following result follows:

proposition 5: For $K/Z > \delta_H$, real investor control in good projects is decreasing in α_g, and real investor control is bad projects in constant in α_g.

Thus, despite the fact that a better informed entrepreneur relinquishes more *formal* control rights to the investor, he has more *real* control over the venture (he faces less intervention). It would be mistaken, though, to conclude that real control is always inversely related to formal control. As will be shown further, formal and real control are both increasing (or decreasing) in changes in other fundamentals, such as entrepreneurial private benefits and pledgeable resources.

B Ex-post Uncertainty

A key premise of our model is that the investor receives additional information during the course of the venture. Obviously, the quality of this ex-post information depends on the uncertainty of the environment. Intuitively, if the ex-post uncertainty increases and, hence, monitoring is more difficult, the probability that a bad project goes undetected increases as well. More investor control is then necessary to deter a bad entrepreneur from seeking financing. Our model therefore implies that formal investor control will be increasing in the ex-post uncertainty.

Let $F^1 = \left(F_g^1, F_b^1\right)$ and $F^2 = \left(F_g^2, F_b^2\right)$ be two information structures. We say that the environment is more uncertain under F^2 than under F^1 if and only if F^2 is a garbling of F^1; that is F^2 can be obtained by adding noise to F^1 :

definition: F^2 is less informative than F^1 if there exists a density $g(t)$ and a constant $\nu \in (0,1)$ such that $\forall t \in (0,1)$:

$$f_g{}^2(t) = \nu f_g{}^1(t) + (1-\nu)g(t), \tag{16}$$

$$f_b{}^2(t) = \nu f_b{}^1(t) + (1-\nu)g(t). \tag{17}$$

The next lemma states that both δ^H and δ^L increase as the ex post uncertainty increases.

lemma 3: If F^2 is less informative than F^1, then $\delta^H(F^2) > \delta^H(F^1)$ and $\delta^L(F^2) > \delta^L(F^1)$.

proof: See Appendix ■

As can be seen in Figure 2, when both δ^H and δ^L increase, it is more difficult to sustain a semi-separating or separating equilibrium for a given level of K/Z. Intuitively, as ex-post uncertainty increases, real investor control decreases for a given level of formal control. The reason is that the investor then relies more on the signal provided by the contract as opposed to his own information. This makes it more difficult to prevent a bad type from pooling with a good type.

Assume now that $K/Z > \delta^H(F^2)$ and, hence, a separating equilibrium exists for both F^1 and F^2. From proposition 3, formal investor control is then given by

$$\gamma^* = \frac{1 - K/Z}{F_b(\hat{t}(\alpha_g)} = \frac{1 - K/Z}{1 - \delta^H}, \tag{18}$$

where $\delta^H(F^2) > \delta^H(F^1)$ and hence $\gamma^*(F^2) > \gamma^*(F^1)$. Thus, formal investor control increases as the ex post uncertainty increases. Intuitively, for a given level of formal control, real investor control is decreasing in the ex post uncertainty. As a result, to prevent a bad type from seeking financing, more formal control needs to be given to the investor under F^2 than under F^1.

The overall impact on real investor control, however, is ambiguous. Indeed, real investor control in good projects equals

$$\gamma^* F_g(\hat{t}(\alpha_g) = (1 - K/Z)\frac{F_g(\hat{t}(\alpha_g)}{F_b(\hat{t}(\alpha_g)}. \tag{19}$$

Whereas $F_g(t)/F_b(t)$ is decreasing in the informativeness of F, it is shown in the Appendix that $\hat{t}(\alpha_g)$ is increasing in the informativeness of F. Intuitively, less ex post uncertainty allows the investor to distinguish better between good and bad projects, which tends to reduce intervention in good projects. On the other hand, the investor also becomes more eager to intervene, as she relies more on her own information. One can show that either effect may dominate. We summarize in the following proposition:

proposition 6: If $K/Z > \delta^H(F^2)$ and F^2 is less informative than F^1, then formal investor control increases as ex post uncertainty increases (that is, a change from F^1 to F^2). The impact on real investor control is ambiguous.

C. Pledgeable Resources and Private Benefits

Two other, potentially measurable, determinants of control are the level of private benefits of the entrepreneur, Z, and his pledgeable resources or stake in the venture, K. The following proposition follows directly from the expressions (18) and (19):

proposition 7: For $K/Z > \delta_H$, *both formal and real investor control are strictly decreasing in* K/Z

The logic behind proposition 7 is straightforward: The smaller K/Z, the more eager is the entrepreneur to seek financing and/or the less he has to lose by giving up control. An entrepreneur who is confident of having a good project then needs to give up more control in order to signal his type. Since neither the investor's information nor beliefs are affected by changes in K/Z, any increase in formal investor control results in a proportional increase in real investor control.

Proposition 7 allows us to relax the assumption that the entrepreneur *must* invest all his resources: Even if only a fraction $K' < K$ were needed to set up the project, the entrepreneur would voluntary invest all his resources in equilibrium as long as $K < Z$. The reason is that a larger K reduces the amount of control rights that needs to be given to the investor, hence avoiding inefficient intervention. Note that if K were to be larger than Z, no signaling would be necessary. Indeed, a bad type then prefers not to continue with the project.

The above *substitution between capital contribution and investor control* might explain why signaling with control rights is so prevalent in *venture capital*. Indeed, start-ups typically have limited financial resources to co-invest and K is best interpreted as the opportunity cost of time for doing the venture. The only option to signal quality may then be to relinquish control rights. In contrast, a mature firm might be able to co-invest a much larger amount and, hence, avoid giving up substantial control rights to investors.

In the case of a mature firm seeking financing, a natural extension of our model would be to give firms the option to co-invest more money in the venture, but to assume that the cost of capital may exceed its value in the venture. For example, the firm might need to sell some of its existing assets to raise capital. A larger co-investment reduces the cash-flow claim W, which needs to be given to the investor. Since a bad type never recovers anything from the cash-flows, however, co-investing in the venture is very costly. A good type, in contrast, gets a higher return when the project is successful. Signaling through the size of the co-investment is thus an alternative to signaling with control rights. The relative benefits of using control as a signalling device depend on the ex post uncertainty. Intuitively, if the investor can better distinguish between good and bad projects ex post, she will intervene less in good projects for a given level of intervention in bad projects. The relative benefits of co-investing a larger amount, on the other hand, depend on the opportunity costs of such a co-investment. If this per dollar opportunity cost is increasing in the size of the co-investment, a firm is likely use both control rights and co-investment to signal project quality. Whereas a full investigation of such joint signalling is outside the scope of this paper, the conclusion is likely to be that the investor will receive less control rights when the firm can easily increase its co-investment.

D. Comparative statics in Semi-separating and Pooling Equilibria

Since multiple equilibria exist for $K/Z < \delta_H$ and different refinements may select different equilibria, making comparative static predictions is somewhat tricky. To provide some insights, we will make the (strong) assumption that for $K/Z \in (\delta_L, \delta_H)$, players play the semi-separating equilibrium.[23]To the extent that pooling equilibria may occur, however, our results should be interpreted with some caution.

- For $K/Z \in (\delta_L, \delta_H)$, the semi-separating equilibrium with $\gamma^* = 1$ is played. **(A4)**

Since δ_H is increasing in both α_g and the ex post-uncertainty, a first consequence of assumption $A4$ is that an increase in ex ante asymmetric information, ex post-uncertainty or entrepreneurial private benefits Z make it more difficult to sustain an equilibrium with limited investor control. Secondly, while formal investor control equals 1 for $K/Z \in (\delta_L, \delta_H)$, the information structure then affects the fraction of bad types which obtain financing and, hence, the *average quality of financed projects.* This average project quality, in turn, affects *real investor control* in equilibrium:

proposition 8: Given $A4$, *keeping observed project quality fixed:*
(i) A increase in the asymmetric information, α_g, *an increase the ex-post uncertainty, or a decrease in* K/Z *may result in a shift from a separating equilibrium with* $\gamma^* < 1$ *to a semi-separating equilibrium where* $\gamma^* = 1$, *but never the other way around.*

(ii) As long as $K/Z \in (\delta_L, \delta_H)$, the average quality of a financed project is constant in α_g, decreasing in the ex-post uncertainty and increasing in K/Z.

(iii) As long as $K/Z \in (\delta_L, \delta_H)$, real investor control in a good project is constant in α_g, increasing in the ex-post uncertainty and decreasing in K/Z. Real investor control in bad projects is constant.

The first observation generalizes the comparative statics results on formal investor control obtained for $K/Z > \delta_H$. The second and third observation discuss the comparative statics with respect to average project quality and real investor control. First, an increase in the average project quality of good types, α_g, does not affect the average quality of all financed projects as it is exactly compensated by an increase in the fraction of bad types that seek financing. As a result, real investor control in the average project is also independent of α_g. Second, an increase in the ex post uncertainty only increases the fraction of bad types that seek financing and, hence, lowers the average quality of a financed project. Since a bad type must be indifferent between seeking financing or not in equilibrium, real investor control in a bad project always equals $F_b(\hat{t}(\beta^s) = 1 - K/Z$. In contrast, real investor control in a good project can be rewritten as

$$F_g(\hat{t}(\beta^s) = \frac{F_g(\hat{t}(\beta^s)}{F_b(\hat{t}(\beta^s)}(1 - K/Z), \tag{20}$$

where we show in the Appendix that $F_g(\hat{t}(\beta^s)/F_b(\hat{t}(\beta^s)$ is decreasing in the ex post uncertainty. Intuitively, an increase in the ex post uncertainty implies that it is more difficult to distinguish between good and bad projects. Since the probability of intervention in bad projects is constant in equilibrium, this unavoidably results in more frequent interventions in good projects. Finally, also a decrease in K/Z results in more pooling and a lower average project quality. This lower project quality, in turn, makes the investor more eager to intervene in any project. Indeed, since $F_b(\hat{t}(\beta^s) = 1 - K/Z$, it follows that both $\hat{t}(\beta^s)$ and $F_g(\hat{t}(\beta^s)$ are increasing in $1 - K/Z$.

For $K/Z < \delta_L$, only pooling equilibria exists. While we prefer to remain agnostic as to which pooling equilibrium then prevails, a unique equilibrium can be obtained by either applying Cho and Kreps' (stronger) D1 criterion or, as in Diamond (1991), by selecting the equilibrium that is preferred by the good type. As shown in the Appendix, the D1 criterion always selects the pooling equilibrium with full investor control. In contrast, the expected utility of a good type is increasing in formal investor control if and only if

$$\frac{1-\alpha}{\alpha}v > \frac{1-\alpha_g}{\alpha_g}Z + \frac{F_g(\hat{t}(\alpha))}{F_b(\hat{t}(\alpha))}\left[1+Z-v\right]. \quad (21)$$

Intuitively, if α is sufficiently small – that is the fraction of bad types in the population is sufficiently large – the liquidation of bad projects may substantially reduce the finance costs of a good type. A good type then prefers to give as much formal control to the investor as possible. A necessary condition, however, is that $\alpha_g - \alpha$ is sufficiently large. This implies that if one follows the equilibrium selection proposed in Diamond (1991), for $K/Z < \delta_L$, an increase in asymmetric information may result in a shift from an equilibrium with minimal investor control to the equilibrium with full investor control, but never the other way around. This is consistent with the comparative statics predictions in a semi-separating or separating equilibrium. On the other hand, unlike for $K/Z > \delta_H$, changes in the informativeness of F have an ambiguous effect, whereas an increase in entrepreneurial private benefits makes the minimal investor control more attractive.

E. Empirical Evidence

The relationship among asymmetric information, general uncertainty, and investor control is consistent with empirical findings on control rights in venture capital and technology alliances.

Venture Capital: Kaplan and Strömberg (2003) find that VCs are more likely to have board and voting control in pre-revenue ventures, where the uncertainty about the viability of the venture should be higher, and in industries with a higher volatility such as R&D-intensive industries; in contrast, they are less likely to have voting control with repeat entrepreneurs. As they argue: "These results indicate that when the uncertainty about the venture and the quality of the founder is higher, the VC is allocated more control" (page 302). Gompers (1998) reports similar findings. One shortcoming of the above studies is that they rely on proxies for uncertainty and asymmetric information. By using the direct risk assessments in investment memos produced by 11 VC firms for investments in 67 portfolio companies, Kaplan and Strömberg (2004) are able to construct more precise risk measures. In particular, they distinguish between *external risk,* such as market size, customer adoption, competition, and *internal risks;* that is, risks associated with asymmetric information about management quality and actions. They find that an increase in both internal and external risks is associated with significantly more investor control. While it seems very likely that internal risks are subject to private information, this is perhaps more questionable for external risks. Our model, however, predicts that an increase in asymmetric information as well as an increase in (non-asymmetric) uncertainty result in more investor control. Note further that the presence of two-sided asymmetric information, where the venture capitalist also possesses private information, is compatible with our model and its results. As argued previously, we only require that the entrepreneur possess some private information, not that he be better informed than the investor.

Technology Alliances: Lerner and Merges (1998) examine the determinants of control rights in a sample of 200 alliances between a (small) biotechnology firm and a (large) pharmaceutical concern. Lerner and Merges find that projects in their early stages at the time of the alliance formation assign more control to the financing firm (i.e., the pharmaceutical concern) even when controlling for the financial resources of the biotechnology firm. Intuitively, these are the stages where the uncertainty and informational asymmetries are most extreme, and the biotechnology firm is most likely to have private information concerning its own project.

A notable short-coming in the empirical literature is its focus on formal control, not real control. The only exception is Hellman and Puri (2002), who investigate the real impact that venture capitalists have on the development of new firms. Given our theoretical results, it would be interesting to see empirically how strong the correlation is between formal investor control and actual investor interference.

IV. Contingent Control Rights

One of the findings of Kaplan and Strömberg (2003) is that voting rights and control rights in ventures are often contingent on observable measures of financial and non-financial performance. The investor, for example, may receive control if the firm's EBIT — earnings before interest and taxes — or its net worth falls below a threshold. Examples of non-financial contingencies are product functionality or performance, approval of a product by the Federal

Drug Administration, or being granted a patent. In general, control is allocated such that if the firm performs poorly, the investor obtains full control. As firm performance improves, the entrepreneur retains/obtains more control rights.

Let us, therefore, assume that control can be made contingent on a *verifiable measure of performance* z, $\gamma \equiv \gamma(z)$, which is correlated with the ex-post information of the investor t.[24] For concreteness, we assume $z \equiv t + \eta$, where $\eta \sim \mathcal{N}(0, \sigma_\eta^2)$ independent of the entrepreneur's type.[25] The noise η stands for all the information learned by the investor during the course of the venture that is not reflected in the verifiable measure z. How can contingent control rights improve upon a random (unconditional) control allocation? Intuitively, contingent control rights may be useful as a way to *selectively* reduce the probability of intervention. In particular, if a separating equilibrium exists, there is excess intervention for $\gamma = 1$, and one would optimally like to prevent the investor from intervening for values of t close to $\hat{t}(\alpha_g)$, where the investor is most likely to mistakenly intervene in good projects. A random control allocation, however, reduces the probability of intervention across the board for all values of $t < \hat{t}(\alpha_g)$. Making control contingent on $z = t + \eta$ can improve upon this. Since bad projects are more likely for low values of z, the optimal conditional control allocation takes the form of $\gamma(z) = 1$ for $z \leq z^c$ and $\gamma(z) = 0$ if $z > z^c$, where z^c is such that

$$1 - \Pr(t + \eta \leq z^c \wedge t \leq \hat{t}(\alpha_g) | r = 0) = K/Z. \tag{22}$$

While keeping the threat of intervention constant for a bad type, this control allocation decreases the probability of intervention faced by a good type. Neatly consistent with the findings of Kaplan and Strömberg (2003), we thus find that *control shifts to the investor if performance is bad* ($z < z^c$).

The same comparative static results hold as in our basic model. From (22), since $\hat{t}(\alpha_g)$ is decreasing in α_g, z^c must be increasing in α_g : As the entrepreneur is better informed, the investor receives control *in more states of nature.* Similarly, it can be shown that z^c increases if the post-contractual information of the investor is more noisy or Z/K is larger.

If no separating equilibrium exists, the semi–separating equilibrium in which the investor receives full control continues to pareto-dominate all other semi-separating equilibria, as it minimizes the amount of pooling by bad types.[26] We summarize in the next proposition.

proposition 9: If $z = t + \eta$ is contractible, then:

If $K/Z > \delta_H$, there exists a unique separating equilibrium in which a good entrepreneur offers a contract specifying

$$\gamma(z) = 1 \quad \text{for all } z \leq z^c \tag{23}$$

$$\gamma(z) = 0 \quad \text{for all } z > z^c, \tag{24}$$

*where z^c, given by (22), is (i) increasing in α_g, with $\lim_{\alpha_g \to \beta^s} z^c = +\infty$; (ii) decreasing in the ex post uncertainty, as characterized by the informativeness of $F(t)$;*and *(iii) increasing in Z/K.*

If $K/Z \in (\delta_L, \delta_H)$, all semi-separating equilibria specifying $\gamma(z) < 1$ for all or some values of z are pareto-dominated by the semi-separating equilibrium with full investor control.

proof: See Appendix. ■

Note, finally, that it makes no sense to make W contingent on z. Since a bad type never has to pay W, it is costless for him to mimic any cash-flow claim offered by a good type. Hence, W cannot be used as a signaling device.[27]

Elfenbein and Lerner (2003) test the above predictions in the context of a sample of over 100 Internet portal alliance contracts. Such contracts frequently contain contingencies based on performance measures of the partner. Typically, these contingencies would grant the portal certain rights, such as termination or renegotiation, if they are not met. Consistent with our model, they find that when uncertainty is larger, as measured by the maturity of the partner's industry, portals are granted significantly more contingent control rights.

V. Alternative Interpretations

Before we conclude, we provide two alternative interpretations of our model. First we take our analysis a step further and show that our results carry through if the difference between a good and a bad project is not its quality, but whether or not the returns are transferable. This supports our claim that control rights are a signal of congruence. Second, we show how investor control can be implemented by issuing short-term debt. In particular, the investor then can gain control over the venture by refusing to refinance it.

A Signaling Congruence as opposed to Project Quality.

In this section, we strengthen our claim that relinquishing control rights is a signal of congruence of interests, rather than just project quality. For this purpose, we consider a case where the difference between good and bad projects is entirely driven by whether their returns are transferable or not. Asymmetric information and signaling with control rights is then purely about congruence of preferences, not about project quality.

Assume that a project yields transferable cash flows with probability α, and non-transferable private benefits with probability $1-\alpha$. A good type knows that project returns will be verifiable with a probability $\alpha_g > \alpha$. A bad type knows that the project returns will be non-transferable. In both cases, the total (verifiable or non-verifiable) returns of the project equal 1. If the investor has control at date 1, however, she can intervene in the project and obtain a guaranteed return $v < I$, with I as her required investment. Finally, we assume that the project is efficient; that is, $K + I < 1$. Note that in the absence of investor control, a bad type has stronger incentives to seek financing than a good type, as he never needs to share the returns with the investor. As we will show, this may result in a market breakdown.

We analyze the conditions under which a separating equilibrium exists.[28]In a separating equilibrium, a bad type must strictly prefer not to seek financing given an initial investor belief $\beta_0(c) = \alpha_g$. Since the incentives of the investor to intervene in a project are still characterized by lemma 1, the following incentive constraint must be satisfied:

$$1 - \gamma * F_b\left(\hat{t}(\alpha_g)\right) \leq K. \tag{25}$$

Whereas a bad type captures all project returns if the investor does not intervene, a good type needs to share these returns with the investor whenever they are verifiable. Therefore, a good type might not find it worthwhile to seek financing, even if (25) holds at the equality. In contrast to our basic model, we must thus verify whether the participation constraint of a good type is satisfied in the candidate separating equilibrium. This participation constraint will be satisfied whenever a good type's project yields positive net returns in expectations; that is

$$K + I \leq \alpha_g \left[1 - \gamma * F_g\left(\hat{t}(\alpha_g)\right)\right] + (1 - \alpha_g)\left[1 - \gamma * F_b\left(\hat{t}(\alpha_g)\right)\right] \tag{26}$$

$$+ \gamma \left[\alpha_g F_g\left(\hat{t}(\alpha_g)\right) + (1 - \alpha_g) F_b(t(\alpha_g))\right] v, \tag{27}$$

or, equivalently,

$$K + I \leq 1 - \gamma * F_b\left(\hat{t}(\alpha_g)\right) + \alpha_g \gamma \left[F_b\left(\hat{t}(\alpha_g)\right) - F_g\left(\hat{t}(\alpha_g)\right)\right](1 - v) + \gamma F_b(t(\alpha_g))v. \tag{28}$$

The RHS of (28) denotes the expected (transferable or non-transferable) gross returns of a good type's project, the LHS the required investment. Assume now that investor control γ is such that a bad type is indifferent between seeking financing or not. Substituting (25) at equality in (28), a good type strictly prefers to seek financing if and only if

$$\alpha_g \left[1 - \frac{F_g\left(\hat{t}(\alpha_g)\right)}{F_b\left(\hat{t}(\alpha_g)\right)}\right](1 - v) + v \geq \frac{I}{1 - K}. \tag{29}$$

It is easy to see that (29) will always be verified whenever $(1 - K) * v \geq I$.

propostion 10: (i) If $K \geq \delta_H$ and (29) holds, then:

- There exists a unique separating CK-equilibrium in which a good type offers a contract c, specifying γ^* given by $K = 1 - \gamma^* F_b\left(\hat{t}(\alpha_g)\right)$.

- Investor control is strictly increasing in the ex ante asymmetric information, as characterized by α_g, is strictly increasing in the ex post uncertainty as characterized by $F = (F_g, F_b)$, and is strictly decreasing in K.

(ii) If $K \geq \delta_H$ but (29) is violated, no CK-equilibrium exists in which a project receives financing.

proof: The proof is analogue to that of the corresponding results in Sections II and III. ■

As in our basic model, the least-cost separating equilibrium is the unique CK equilibrium, and similar comparative statics hold. The obtained result, however, is somewhat stronger, since in the absence of investor control, bad types derive a larger benefit from obtaining financing than good types. Nevertheless, assigning control rights to the investor may overcome this adverse selection.

Note, finally, that a bad type now has a larger incentive to pledge costly collateral or assets than a good type. Therefore, a good type cannot use capital structure to signal his type as proposed in the previous section. This suggests that one may expect signaling through control rights to be particularly prevalent when asymmetric information is purely related to congruence of preferences, rather than project quality.

B. Short-term versus Long-term Financing

Next, we consider a variant of our model where in order to complete the project, the entrepreneur needs $I - v$ at date 0 and v at date 1. To what extent can the intervention decision be viewed as a refusal to refinance the venture? Under which conditions can our model be mapped into a refinancing game? Assume first that the terms of refinancing cannot be prearranged; that is, the refinancing constitutes a proper new round. Let w_1 be the face value of the first claim to be repaid at date 1. Provided that t is a public signal, a competitive financial market will be willing to refinance the entrepreneur if and only if $\beta_1(t) \geq w_1 + v$. As long as $v < \beta_1(t)*I$, however, it is optimal for the initial investor to renegotiate the entrepreneur's debt and refinance the venture. It follows that, as under full investor control, a project financed with short-term debt will be terminated at date 1 if and and only if $t < \hat{t}(\beta_0(c))$. Issuing short-term debt in this setting is thus equivalent to assigning full investor control, with a separating or semi-separating equilibrium existing under the same conditions as in Proposition 3. The only difference is that short-term debt is a discrete variable, whereas we modeled investor control as a continuous variable. Limited investor control, however, can be implemented by using short-term financing where the terms of refinancing are fixed at date 0. If this refinancing can be made contingent on a milestone or benchmark z, correlated with t, this setting is formally identical to that of optimal contingent control rights, as analyzed in Section IV.A. The optimal contract then specifies refinancing if the venture meets a certain performance benchmark.

VI. Concluding Remarks

This paper has developed a theory of the structure of ventures between an entrepreneur and an investor in which asymmetric information and general uncertainty are the main drivers of the allocation of control rights. We have shown that even a small amount of private information on behalf of the entrepreneur results in a substantial shift of control to the investor, as the entrepreneur wants to signal his congruence. Investor control is further increasing in the informational advantage of the entrepreneur and the difficulty of monitoring the venture, and decreasing in the resources of the entrepreneur. Control rights are optimally made contingent on verifiable measures of performance, with control shifting to the investor after bad performance. These predictions stand in contrast with theories on control in organizations, such as Aghion and Tirole (1997) and Dessein (2002), which argue in favor of allocating decision rights to the best-informed party.

Our results are consistent with the observation that investor control is prevalent in venture capital and technology alliances, as compared to other, more traditional, financing arrangements. First, the projects undertaken by start-ups and technology companies are typically surrounded by informational asymmetries. Second, signaling project quality through other means, such as a larger co-investment, can be less effective in the case of new ventures as they tend to have limited pledgeable resources. Furthermore, the relationship among asymmetric information, general uncertainty, and investor control is consistent with empirical findings on control rights in venture capital and technology alliances, as reported by Kaplan and Stromberg (2003,2004) and Lerner and Merges (1998).

In order to establish our results, this paper has challenged the often simplified view on control in corporate finance. While the distinction between formal control (the right to decide) and real control (the effective control over decisions) is known from Aghion and Tirole (1997), its implications are virtually unexplored in corporate finance.[29]The literature on security design and corporate governance assumes that formal and real control are either the same or are positively correlated. In contrast, we show that it is often the *lack* of real investor control that makes it necessary to give the investor more formal control. Similarly, by giving up formal control rights and thus signaling congruence, an entrepreneur may increase his real control over the venture. The applications of the distinction between formal and real control to corporate finance are likely much broader, however. In the context of corporate governance, for example, one might investigate how formal control rights – such as board seats and voting rights – respond (or should respond) to changes in real authority between insiders and outsiders.

APPENDIX

A.I Control as a Signal of Congruence

proof of proposition 3: *(i)* $K/Z \geq \delta_H$: *A unique CK separating equilibrium:*

In any separating Perfect Bayesian Equilibrium (PBE), a good type must offer a contract $c = \{\gamma, W\}$ where $W \leq 1$ must allow the investor to break even in expectations and $\gamma \leq 1$ is such that a bad type weakly prefers not to seek financing; that is, $\gamma \geq \gamma^*$ with γ^* given by

$$1 - \gamma^* F_b(\hat{t}(\alpha_g)) = K/Z. \tag{30}$$

Whenever $K/Z \geq \delta_H$, $\gamma^* \leq 1$. The cash-flow claim W must allow the investor to break-even. Under entrepreneur control, a_o is always implemented, which yields a pay-off W to the investor if the project is successful. Under investor control, renegotiation or intervention yields an expected pay-off of v. It follows that W is uniquely defined by the following expression

$$\begin{aligned} I &= \beta_0(c)\left[(1-\gamma) + \gamma\left(1 - F_g(t^{ren})\right)\right] W \\ &\quad + \gamma\left[\beta_0(c) F_g(t^{ren}) + (1 - \beta_0(c)) F_b(t^{ren})\right] v, \end{aligned} \tag{IR}$$

where t^{ren} is defined by $\beta_1(t^{ren}, \beta_0) \cdot W = v$. Since $I < \alpha$ and $\beta_0(c) = \alpha_g$ in a separating equilibrium, for any γ there always exists a $W^*(\gamma) < 1$ for which (IR) holds at the equality. For $K/Z \geq \delta_H$, there exists thus a range of separating PBE where $\gamma \geq \gamma^*$. However, only the separating PBE that maximizes the expected utility of the good type among all separating PBE will survive the intuitive criterion (the argument is standard and is omitted). Since the investor breaks even in equilibrium, the expected utility of a good type equals the expected gross return of the project minus the investments $K + I$:

$$\alpha_g\left[(1+Z) - \gamma F_g(\hat{t}(\alpha_g))\left[1 + Z - v\right]\right] + (1 - \alpha_g)\left[Z - \gamma F_b\left(\hat{t}(\alpha_g)\right)(Z - v)\right] - I - K. \tag{31}$$

Since (31) is decreasing in γ, the only separating equilibrium that satisfies the intuitive criterion is the one where $\gamma = \gamma^*$. The proof that no pooling equilibrium survives the intuitive criterion is standard and is omitted. For expositional sake, the proof that no semi-separating equilibrium survives the intuitive criterion for $K/Z \geq \delta_H$ is given after we characterize all semi-separating CK equilibria for $K/Z < \delta_H$.

(ii) $K/Z \in (\delta_L, \delta_H)$: *A pareto-dominant semi-separating equilibrium:*

If $K/Z < \delta_H$, no separating equilibrium exists. We now show that for $K/Z \in (\delta_L, \delta_H)$, there exists a range of semi-separating equilibria that can be pareto-ranked and in which a good type offers a contract c specifying $\gamma \leq 1$ and a bad type pools with probability q^*. If $K/Z \leq \delta_L$, no semi-separating equilibrium exists. If $K/Z \geq \delta_H$, semi-separating equilibria exist, but they do not satisfy the intuitive criterion.

ii-a) Existence: In the above described semi-separating equilibrium, Bayesian beliefs imply that

$$\beta_0(c) = \frac{\alpha\alpha_g}{\alpha + (\alpha_g - \alpha)q^*} \in [\alpha, \alpha_g]\,. \tag{32}$$

Since a bad type must be indifferent between pooling and obtaining no financing, q^* must be such that $\beta_0(c) = \beta^s(\gamma)$ where $\beta^s(\gamma)$ is given by

$$1 - \gamma F_b(\hat{t}(\beta^s(\gamma))) = K/Z. \tag{33}$$

Note that $\beta^s(\gamma)$ is increasing in γ and $\beta^s(1) \equiv \beta^s$. We further have that $\beta^s \in (\alpha, \alpha_g)$ if and only if $K/Z \in (\delta_L, \delta_H)$. Define γ' as the amount of investor control for which $\beta^s(\gamma') = \alpha$. It follows that for $K/Z \in (\delta_L, \delta_H)$, there exists a range of semi-separating equilibria in which a good type offers a contract specifying $\gamma \in (\gamma', 1]$ and a bad type pools with probability q^* such that $\beta_0(c) = \beta^s(\gamma)$. No semi-separating equilibrium exists if $K/Z \leq \delta_L$. Indeed, then $\beta^s \leq \alpha$ such that no $q^* < 1$ exists for which $\beta_0(c) = \beta^s(\gamma) \leq \alpha$. If $K/Z > \delta_H$, a range of semi-separating equilibria exists where $\gamma \in (\gamma', \gamma'')$ with $\beta^s(\gamma'') = \alpha_g$. We next show that the latter equilibria do not satisfy the Intuitive Criterion.

ii-b) Intuitive Criterion: Any semi-separating equilibrium in which a good type offers a contract specifying $\hat{\gamma} > \gamma'$ can be supported by investor beliefs $\beta_0(c) = 0$ if $\gamma < \hat{\gamma}$ and $\beta_0(c) = \beta^s(\gamma)$ if $\gamma \geq \hat{\gamma}$.

- Whenever $K/Z \in (\delta_L, \delta_H)$ and thus $\beta^s \in (\alpha, \alpha_g)$, these beliefs satisfy the Intuitive Criterion. Indeed, since $\beta^s < \alpha_g$, it follows from the definition of β^s that a bad type obtains a strictly positive utility if the investor believes he is a good type, regardless of the amount of investor control. Hence, a good type cannot credibly signal his type – and break the equilibrium – by offering more control rights than specified in the equilibrium.

- In contrast, whenever $K/Z \geq \delta_H$ and thus $\beta^s > \alpha_g$, these beliefs do not satisfy the 'Intuitive Criterion'. Indeed, regardless of investor beliefs, a bad type then obtains a strictly negative utility if he offers a contract specifying investor control $\gamma > \gamma^*$ with γ^* given by (30). Hence, according to the intuitive criterion, a good type can credibly signal his type - and break the equilibrium - by offering the investor a control allocation $\gamma > \gamma^*$. It follows that for $K/Z \geq \delta_H$, a semi-separating equilibrium will not satisfy the intuitive criterion whenever a good type obtains a higher expected utility in the least-cost separating equilibrium, characterized above. We next show that this is indeed the case.

ii-c) Pareto-dominance: We now calculate the expected utility of a good type in a semi-separating equilibrium and show that this expected utility is increasing in γ. As $\beta_0(c) = \beta^s(\gamma)$ in a semi-separating equilibrium, the investor would like to intervene if and only if $t < t^s(\gamma) \equiv \hat{t}(\beta^s(\gamma))$. As a bad type is indifferent between seeking financing or not, we have

$$1 - \gamma F_b(t^s(\gamma)) = K/Z. \tag{34}$$

The expected utility of a good entrepreneur is thus given by

$$U_g(\gamma) = \alpha_g(1 - \gamma F_g(t^s(\gamma))) \left[Z + 1 - \bar{W}\right] + (1 - \alpha_g)K - K, \tag{35}$$

where $\bar{W}$ is the expected cash-flow claim that needs to be given to the investor in case $r = 1$,

$$\bar{W} = \frac{I - \gamma\beta^s(\gamma)F_g(t^s(\gamma))v - \gamma(1 - \beta^s(\gamma))F_b(t^s(\gamma))v}{\beta^s(\gamma)(1 - \gamma F_g(t^s(\gamma))}. \tag{36}$$

Substituting $\bar{W}$ and (34), and rearranging some terms, this yields the following utility in a semi-separating equilibrium

$$\begin{aligned} U_g^{ss}(\gamma) \;\; = \;\; & \alpha_g(Z + 1) - \alpha_g(1 - K/Z)\frac{F_g(t^s(\gamma))}{F_b(t^s(\gamma))}\left[1 + Z - v\right] \\ & + (1 - \alpha_g)K - \alpha_g I - \alpha_g\frac{(1 - \beta^s(\gamma))}{\beta^s(\gamma)}\left[I - (1 - K/Z)v\right] - K. \end{aligned} \tag{37}$$

From the MLRP, $F_g(t)/F_b(t)$ is increasing in t. Since $t^s(\gamma)$ is decreasing in γ, then $F_g(t^s(\gamma))/F_b(t^s(\gamma))$ is also decreasing in γ. It follows that the second term of $U_g(\gamma)$ is increasing in γ. Since $\beta^s(\gamma)$ is increasing in γ, the last term of $U_g(\gamma)$ is also increasing in γ. As all other terms are independent of γ, $U_g(\gamma)$ is increasing in γ. It follows that for $K/Z \in (\delta_L, \delta_H)$, the semi-separating equilibrium in which $\gamma = 1$ pareto-dominates all other semi-separating equilibria.

Note: For $K/Z \geq \delta_H$, the expected utility in the least-cost separating equilibrium is given by (37), where γ is such that $\beta^s(\gamma) = \alpha_g$; hence the expected utility for a good type in this least-cost separating equilibrium is higher than in any semi-separating equilibria. Thus, no semi-separating equilibrium satisfies the Intuitive Criterion for $K/Z \geq \delta_H$.

(iii) $K/Z < \delta_H$: Pooling Equilibria:

It is straightforward to see that there exists a range of pooling PBE in which both types propose a contract specifying $\gamma \in [0, \gamma']$ where $\gamma' = 1$ if and only if $\beta^s \leq \alpha$ and γ' is defined by $\beta^s(\gamma') = \alpha$ for $\beta^s > \alpha$. We show now that these pooling PBE satisfy the Intuitive Criterion if and only if $\gamma \in [\gamma^p, \gamma']$, where $\gamma^p > 0$ is given by

$$\gamma^p F_b(\hat{t}(\alpha)) = F_b(\hat{t}(\alpha_g)). \tag{38}$$

Consider first a pooling PBE in which both types relinquish control with probability $\tilde{\gamma} < \gamma^p$. There exists then a probability $\gamma^d < 1$ such that

$$\tilde{\gamma} F_b(\hat{t}(\alpha)) = \gamma^d F_b(\hat{t}(\alpha_g)). \tag{39}$$

It follows that an out-of-equilibrium move in which the entrepreneur offers control rights $\gamma^d + \varepsilon$ – with ε small but positive – is equilibrium dominated for a bad type *regardless of the beliefs of the investor upon observing such a move.* In contrast, for ε sufficiently small, a good entrepreneur would face less intervention by making this out-of-equilibrium move, provided that this credibly reveals his type. Indeed, we have that

$$\gamma^d F_g(\hat{t}(\alpha_g)) = \tilde{\gamma} F_b(\hat{t}(\alpha)) \frac{F_g(\hat{t}(\alpha_g))}{F_b(\hat{t}(\alpha_g))} < \tilde{\gamma} F_g(\hat{t}(\alpha)). \tag{40}$$

Following the logic of the Intuitive Criterion, the investor must therefore place a probability 1 on such a move being made by a good type, which breaks any pooling equilibrium where $\tilde{\gamma} < \gamma^p$. In contrast, any pooling equilibrium where both types relinquish control rights $\tilde{\gamma} \in (\gamma^p, \gamma')$ can be sustained by investor beliefs $\beta_0(c) = 0$ if $\gamma < \tilde{\gamma}$ and $\beta_0(c) = \alpha$ if $\gamma \geq \tilde{\gamma}$. These beliefs satisfy the intuitive criterion, since a bad type would also optimally make an out-of-equilibrium move in which he relinquishes full control, provided that this move would fool the investor into believing him to be a good type. QED.

Expected utility of a Good Type in Pooling Equilibria:

We first investigate which of the many pooling equilibria is preferred by a good type. As in a pooling equilibrium, $\beta_0(c) = \alpha$ the investor would like to intervene if and only if $t < \hat{t}(\alpha)$. The expected utility of a good entrepreneur is thus given by

$$EU_g(\gamma) = \alpha_g(1 - \gamma F_g(\hat{t}(\alpha)) \left[Z + 1 - \bar{W}\right] + (1 - \alpha_g) \left[(1 - \gamma F_b(\hat{t}(\alpha))\right] Z - K, \tag{41}$$

where $\bar{W}$ is the expected cash-flow claim that needs to be given to the investor in case $r = 1$:

$$\bar{W} = \frac{I - \gamma\alpha F_g(\hat{t}(\alpha))v - \gamma(1-\alpha)F_b(\hat{t}(\alpha))v}{\alpha(1 - \gamma F_g(\hat{t}(\alpha)))}. \tag{42}$$

Substituting $\bar{W}$ and (34), and rearranging some terms, this yields the following utility in a pooling equilibrium

$$\begin{aligned} EU_g^P(\gamma) \quad &= \quad \alpha_g(Z+1) - \alpha_g \gamma F_g(\hat{t}(\alpha)) \left[1 + Z - v\right] ` \\ &\quad -\alpha_g I - \alpha_g \frac{(1-\alpha)}{\alpha} \left[I - \gamma F_b(\hat{t}(\alpha))v\right] \\ &\quad +(1-\alpha_g) \left[(1 - \gamma F_b(\hat{t}(\alpha))\right] Z - K. \end{aligned} \tag{43}$$

It follows that the expected utility in a pooling equilibrium is increasing in γ if and only if

$$\alpha_g \frac{(1-\alpha)}{\alpha} v - \alpha_g \frac{F_g(\hat{t}(\alpha))}{F_b(\hat{t}(\alpha))} [1 + Z - v] - (1-\alpha_g) Z > 0, \tag{44}$$

which is never verified if α is sufficiently small.

Secondly, we investigate when, for $K/Z \in (\delta_L, \delta_H)$, a good type prefers the semi-separating equilibrium over any pooling equilibria. Since the semi-separating equilibrium with $\gamma = 1$ pareto-dominates all semi-separating equilibria with $\gamma < 1$, it also pareto-dominates the pooling equilibrium with maximal investor control $\gamma = \gamma'$. Hence, a good type will strictly prefer the semi-separating equilibrium if and only if a good type prefers this semi-separating equilibrium over the pooling equilibrium where $\gamma = \gamma^p$ given by

$$\gamma^p F_b(\hat{t}(\alpha)) = F_b(\hat{t}(\alpha_g)). \tag{45}$$

Substituting $\gamma = \gamma^p$ in (43) and setting $\gamma = 1$ in expression (37), it follows that a good type strictly prefers the semi-separating equilibrium with $\gamma = 1$ over any pooling equilibrium if and only if

$$\begin{aligned} & \alpha_g(Z+1) - \alpha_g(1-K/Z)\frac{F_g(\hat{t}(\beta^s))}{F_b(\hat{t}(\beta^s))} [1 + Z - v] \\ & +(1-\alpha_g)K - \alpha_g I - \alpha_g \frac{(1-\beta^s)}{\beta^s} [I - (1-K/Z)v] - K \\ > \; & \alpha_g(Z+1) - \alpha_g F_b(\hat{t}(\alpha_g)) \frac{F_g(\hat{t}(\alpha))}{F_b(\hat{t}(\alpha))} [1 + Z - v] \\ & -\alpha_g I - \alpha_g \frac{(1-\alpha)}{\alpha} \left[I - F_b(\hat{t}(\alpha_g)))v\right] + (1-\alpha_g)\left[(1 - F_b(\hat{t}(\alpha_g))\right] Z - K \end{aligned} \tag{46}$$

or still

$$\begin{aligned} & F_b(\hat{t}(\alpha_g)) \frac{F_g(\hat{t}(\alpha))}{F_b(\hat{t}(\alpha))} [1 + Z - v] + \frac{1-\alpha}{\alpha} \left[I - F_b(\hat{t}(\alpha_g))v\right] \\ > \; & (1-K/Z)\frac{F_g(\hat{t}(\beta^s))}{F_b(\hat{t}(\beta^s))} + \frac{(1-\beta^s)}{\beta^s} [I - (1-K/Z)v] + \frac{(1-\alpha_g)}{\alpha_g} \left[\left[(1 - F_b(\hat{t}(\alpha_g))\right] Z - K\right]. \end{aligned} \tag{47}$$

For K/Z very close to δ_H, we have that $1 - K/Z \cong F_b(\hat{t}(\alpha_g))$ and $\beta^s > \alpha$. Since $\frac{F_g(\hat{t}(\alpha))}{F_b(\hat{t}(\alpha))}$ is decreasing in α, it thus follows that the pooling equilibrium is then never preferred.

As K/Z tends to δ_L, the expected utility of a good type in the semi-separating equilibrium tends to the latter's expected utility in the pooling equilibrium with maximal investor control. The semi-separating equilibrium is then preferred over any pooling equilibrium if and only if (44) holds.

A.II Determinants of Investor Control

preliminaries: If F_2 is less informative than F_1 as defined in the text, then

- $\zeta^2((t) = f_g^2(t)/f_b^2(t) = 1 \Leftrightarrow \zeta^1(t) = 1$
- $\zeta^1(t) < \zeta^2(t) \Leftrightarrow \zeta^2(t) < 1$
- $F_g^1(t)/F_b^1(t) < F_g^2(t)/F_b^2(t) < 1$ for any t.

In addition, one can always rescale t under information structure F^1 such that the last condition becomes

- $F_g^1(t) < F_g^2(t)$ and $F_b^1(t) > F_b^2(t)$ for any t.

proof of lemma 3: Define by $\hat{t}(\beta_0, F^i)$ the intervention threshold given belief β_0 and information structure F^i. Since $\alpha_g > \alpha > v$, it follows from lemma 1 that

$$\zeta^1(\hat{t}(\alpha, F^1)) = \zeta^2(\hat{t}(\alpha, F^2)) < 1 \quad \text{and} \quad \zeta^1(\hat{t}(\alpha_g, F^1)) = \zeta^2(\hat{t}(\alpha_g, F^2)) < 1. \tag{48}$$

Hence, from the preliminaries above and the MLRP

$$\hat{t}(\alpha, F^1) > \hat{t}(\alpha, F^2) \quad \text{and} \quad \hat{t}(\alpha_g, F^1) > \hat{t}(\alpha_g, F^2), \tag{49}$$

and thus also $F_b^1(\hat{t}(\alpha, F^1)) > F_b^2(\hat{t}(\alpha, F^2))$, and $F_b^1(\hat{t}(\alpha_g, F^1)) > F_b^2(\hat{t}(\alpha_g, F^2))$, from which

$$\delta^L(F^1) < \delta^L(F^2) \quad \text{and} \quad \delta^H(F^1) < \delta^H(F^2). \tag{50}$$

Finally, since $\beta^s(F^i) = \alpha_g \Leftrightarrow \delta^H(F^i) = K/Z$, and since $\delta^H(F_i)$ is increasing in α_g, it follows from $\delta^H(F^2) > \delta^H(F^1)$ that $\beta^s(F^2) < \beta^s(F^1)$. QED.

D1-criterion: Criterion D1 says that if the set of the investor's responses that make a bad type willing to deviate from the equilibrium contract c^* to a contract c' is strictly smaller than the set of responses that make a good type willing to deviate, then the investor should believe that the good type is infinitely more likely to deviate to c' than the bad type. Hence, in any pooling or semi-separating equilibrium for which $\gamma \in [\gamma', 1)$, both types are strictly better off to relinquish full control ($\gamma = 1$), since the investor then assigns a probability 1 to the entrepreneur being of the good type. It follows that no pooling or semi-separating CK-equilibrium satisfies $D1$ unless $\gamma = 1$.

A.III Contingent Control rights

proof of proposition 9: (i) $K/Z > \delta_H$: The characterized separating equilibrium is an equilibrium: from condition (22), the probability of intervention faced by a bad type is such that the latter is indifferent between seeking financing or not. The above equilibrium will be the *unique* CK-equilibrium if it is preferred by the good entrepreneur over the separating equilibrium with probabilistic control allocation $\gamma = \gamma^*$, discussed in the previous section, and any other separating equilibrium with contingent control rights.[30]

Let us denote by $\theta = \theta_g$ the state of nature in which the project will be successful (yield $r = 1$) and by $\theta = \theta_b$ the state of nature in which the project will fail. Since the incentive constraint of a bad type fixes the probability of intervention in bad projects, one separating equilibrium will be preferred over another if it involves a lower probability of intervention in good projects. Thus, the contingent control allocation of Proposition *9* will be preferred over the probabilistic control allocation γ^* if and only if

$$\gamma^* F_g(\hat{t}(\alpha_g)) > E\left[\Pr(t + \eta \leq z^c, t \leq \hat{t}(\alpha_g) \mid \theta = \theta_g)\right], \tag{51}$$

where expectations are taken over η. Since $\gamma^* = (1 - K/Z)/F_b(\hat{t}(\alpha_g))$ and

$$\Pr(t + \eta \leq z^c, t \leq \hat{t}(\alpha_g) \mid \theta = \theta_b) = 1 - K/Z, \tag{52}$$

(51) is equivalent to

$$\frac{E\left[\Pr(t \leq z^c - \eta, t \leq \hat{t}(\alpha_g) \mid \theta = \theta_b)\right]}{F_b(\hat{t}(\alpha_g))} > \frac{E\left[\Pr(t \leq z^c - \eta, t \leq \hat{t}(\alpha_g) \mid \theta = \theta_g)\right]}{F_g(\hat{t}(\alpha_g))}, \tag{53}$$

which will be satisfied if and only if

$$\begin{aligned} \Leftrightarrow \quad & \frac{E\left[\Pr(t \leq z^c - \eta, t \leq \hat{t}(\alpha_g) \mid \theta = \theta_b) \mid \eta > z^c - \hat{t}(\alpha_g))\right]}{F_b(\hat{t}(\alpha_g))} \\ > \quad & \frac{E\left[\Pr(t \leq z^c - \eta, t \leq \hat{t}(\alpha_g) \mid \theta = \theta_g) \mid \eta > z^c - \hat{t}(\alpha_g))\right]}{F_g(\hat{t}(\alpha_g))}. \end{aligned} \tag{54}$$

Finally, the latter condition will be satisfied if

$$\forall \eta \in \left(z^c - \hat{t}(\alpha_g), z^c\right) : \frac{F_b(z^c - \eta)}{F_b(\hat{t}(\alpha_g))} > \frac{F_g(z^c - \eta)}{F_g(\hat{t}(\alpha_g))}. \tag{55}$$

From the MLRP, $F_g(t)/F_b(t)$ is increasing in t. Hence, the previous inequality indeed holds whenever $\eta > z^c - \hat{t}(\alpha_g)$. In a similar way, one can also show that any other separating equilibria with a contingent control allocation that differs from the one specified in Proposition *9* results in more intervention in bad projects.

(ii) For $K/Z \in [\delta_L, \delta_H]$, no separating equilibrium with contingent control rights exists. Let us now evaluate potential semi-separating equilibria in which a good type offers a contract c specifying contingent control rights $\gamma(z)$ where $\gamma(z) \neq 1$ for some values of z. In such a semi-separating equilibrium, it must be that $\beta_0(c) < \beta^s$. Indeed, suppose that $\beta_0(c) = \beta^s$, then a bad type would face intervention with probability $\gamma(z)$ whenever $t < \hat{t}(\beta^s)$. Since $\gamma(z) < 1$ and $t < \hat{t}(\beta^s)$ with positive probability, this probability of intervention would be smaller than $F_b(\hat{t}(\beta^s))$ and the IC constraint of a bad type would be violated. Hence, in any semi-separating equilibrium with contingent control rights, it must be that $\beta_0(c) < \beta^s$. In the same way as for semi-separating equilibria where $\gamma < 1$ and $\beta^s(\gamma) < \beta^s$, one can use this to show the expected utility of a good type is therefore strictly lower than in the semi-separating equilibrium in which $\gamma = 1$ and $\beta_0(c) = \beta^s$.

(iii) *Comparative static results for $K/Z > \delta_H$* : We must show that z^c , given by

$$\Pr(t + \eta \leq z^c, t \leq \hat{t}(\alpha_g) \mid \theta = \theta_b) = 1 - K/Z, \tag{56}$$

is increasing in α_g, with $\lim\limits_{\alpha_g \to \beta^s} z^c = +\infty$, decreasing in the informativeness of $F(t)$, and increasing in Z/K.

a) Since $\hat{t}(\alpha_g)$ is decreasing in α_g, it follows from (56) that z^c is increasing in α_g and $\lim\limits_{\alpha_g \to \beta^s} z^c = +\infty$.

b) Consider two information structures F^2 and F^1, where F^2 is less informative than F^1. We show that $z^c(F^2) > z^c(F^1)$.We can rewrite the left-hand side of (56) as

$$E\left[F_b(z^c - \eta)\right] * F_b(\hat{t}(\alpha_g), \tag{57}$$

from which it must be that

$$E\left[F_b^1(z^c(F^1) - \eta)\right] * F_b^1(\hat{t}(\alpha_g, F^1) = E\left[F_b^2(z^c(F^2) - \eta)\right] * F_b^2(\hat{t}(\alpha_g, F^2). \tag{58}$$

Since from Lemma 3, $\delta^H(F^2) > \delta^H(F^1)$, if follows that $F_b^2(\hat{t}(\alpha_g, F^2)) < F_b^1(\hat{t}(\alpha_g, F^1))$ and thus necessarily

$$E\left[F_b^1(z^c(F^1) - \eta)\right] < E\left[F_b^2(z^c(F^2) - \eta)\right]. \tag{59}$$

Since $F_b^1(t) > F_b^2(t)$ for any t, it follows that $z^c(F^1) < z^c(F^2)$.

c) Since t^s is given by $F_b(t^s) = 1 - K/Z$, it follows that t^s is decreasing in K/Z. Since $\hat{t}(\alpha_g)$ is independent of K/Z, from (56), z^c is decreasing in K/Z. ■

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FOOTNOTES

1. The distinction between formal authority – i.e., the right to decide – and real authority – i.e., the effective control over decisions due to one's superior information – was introduced in the economic literature by Aghion and Tirole (1997).

2. Gompers (1998), for example, documents that covenants are frequently used to give the venture capitalist the right to control the board of directors, approve major expenditures, replace the entrepreneur, or liquidate the firm. Similarly, Kaplan and Strömberg (2003) find that venture capital contracts separately allocate cash-flow rights, board rights, voting rights, liquidation rights, and other control rights. See also Sahlman (1990) and Lerner (1995). In biotech alliances, the prerogatives of parties in every stage of the process are carefully delineated in the agreements, ranging from the allocation of research dollars and the management of clinical trials to the ownership of patents and know-how (Lerner and Merges (1998)). The financing firm may further receive the right to terminate particular projects, cancel the alliance, or shelve the projects.

3. Entrepreneurs who have founded another venture previously.

4. Firms entering into alliances exhibit considerable heterogeneity. In some cases, the technologies covered by the alliance are well along the way to regulatory approval. In other cases, they are in the very earliest stages of research exploration.

5. See Hart (2001) for a more detailed discussion.

6. On the other hand, Casamatta (2003), Hellman (1998), Hellman and Puri (2002) and Schmidt (2003), among others, have emphasized the active involvement and support of venture capitalists in the venture, leading to a double moral hazard problem. Hellman (1998), for example, argues that investor control may be useful since it protects the venture capitalist from hold-up by the entrepreneur when looking for a superior management team.

7. Building on Aghion and Bolton (1992), Dewatripont and Tirole (1994) provide another rationale for contingent control rights. In the context of a publicly held company, they show that shareholders optimally receive control in good states of nature, and debt-holders receive control in bad states of nature. Such a capital structure reduces managerial moral hazard, as

shareholders share the same objectives as management (and, hence, are passive), but debtholders do not (they like to intervene). Also Berglof (1994), Hellman (2002), and Schmidt (2003) have contingent control in their models.

8. In our model, the financial claim of the investor can be interpreted as both debt or equity.

9. These resources could be purely financial or a mix of both financial and physical/human capital.

10. As argued by Lerner and Merges (1998): "In particular, firms that contract to perform R&D in alliances frequently have ongoing research projects of their own, in addition to the contracted efforts. In case of a dispute, it may be very difficult for the financing firm to prove that the R&D firm has employed alliance resources to advance projects which are not part of the alliance" (pp. 126-127).

11. The assumption that Z is independent of the state of nature is wlog. Our results would not be qualitatively affected if private benefits were larger (smaller) if the project is a failure.

12. With the exception of the structure of cash-flow claims, our results would not be qualitatively affected if a_R were as risky as a_o, and $v < \alpha$ simply denoted the (independent) success probability of a_R. This would make the analysis much more messy, however, as the entrepreneur's cash-flow claim in case $r = 1$ then enters the incentive constraint of the type who knows that the initial project is a lemon.

13. More generally, our results would not be qualitatively affected if an entrepreneur, upon receiving a bad signal, assigned a positive probability $\lambda < \alpha$ to success. Indeed, in a separating equilibrium, the posterior of the investor, which plays a very important role in our analysis, is independent of λ. In a semi-separating equilibrium (see below), λ does enter the posterior of the investor, but the posterior would still be decreasing in the amount of pooling by bad types, which is all that is needed. The assumption that there are only false positives ($\lambda = 0$) significantly simplifies the analysis, however, as it implies that the incentive constraint of the bad type is independent of the cash-flow claim of the investor in case $r = 1$.

14. One way to model this is to assume that if the project is a lemon, then this is revealed

to two competing investors with positive probability, independently of the entrepreneur's type. If the investors receive no unfavorable information, then they assign a probability α to the project being successful. While the entrepreneur observes only his own signal, the investors then automatically reveal that they did not receive unfavorable information by agreeing to finance the venture.

15. As is standard in adverse selection models, we assume that parties can commit not to renegotiate immediately after signing the contract at date 0. While ex post attractive, ex ante such renegotiation would obviously destroy any signaling equilibrium. One could formalize this by assuming that the investor deduces that the entrepreneur is of a bad type if he is willing to renegotiate investor control.

16. They can be thought of as the effort choice of moral hazard models, with the difference that the identity of the agent who has to make the effort decision (who has the authority over the action) is not exogenously given, but endogenous. As Bolton and Dewatripont (2001) argue, this seems reasonable for "actions like business strategies where 'the devil is in the details' (...) so that the only thing that can be done is to 'put somebody in charge of the job'"(Chapter 13, Foundations of Contracting with Unverifiable Information).

17. Since the pay-off of a bad entrepreneur is independent of W, such a cash-flow offer cannot have any signalling value. Similarly, a change in control rights cannot have a signaling value, since no new information arises.

18. Without loss of generality, we assume that $\lim_{t \to -\infty} \zeta(t) = 0$ and $\lim_{t \to -\infty} \zeta(t) = +\infty$.

19. In a two-type model, an equilibrium does not satisfy the 'Intuitive Criterion' if there exists an out-of-equilibrium move that always reduces the pay-off of one type (relative to his equilibrium pay-off), but would increase the equilibrium pay-off for the other type if it were to reveal his type. Any reasonable equilibrium belief should therefore assign a probability zero to this move being made by the former type, which breaks the equilibrium.

20. A natural way to interpret these semi-separating equilibria is to assume that entrepreneurs are *heterogeneous in the private benefit* they derive from the project. The private benefit of the entrepreneur, for example, could be given by $Z - x\varepsilon$, with ε very small but positive and x a privately known characteristic of the entrepreneur, uniformly distributed on $[0, 1]$.

In a semi-separating equilibrium, only bad entrepreneurs of type $x \leq q^*$ then seek funding.

21. Indeed, consider a candidate equilibrium in which the entrepreneur always keeps full control. Regardless of subsequent investor beliefs, a bad type then never benefits from an out-of-equilibrium move in which he relinquishes some control rights to the investor. In contrast, a good type would benefit from such a move, provided that this credibly reveals his type. According to the intuitive criterion, the investor must therefore assign probability one to the entrepreneur being a good type upon observing this move, which breaks the pooling equilibrium. In the Appendix, we show that in order for pooling equilibria to satisfy the intuitive criterion, the investor must receive control rights above some threshold γ_p.

22. This is consistent with Cho and Kreps' (stronger) D1 criterion. Fudenberg and Tirole (1991), chapter 11, provides a general discussion of D1 and related equilibrium refinements in signaling equilibria. For K/Z close to δ_H, this is also always the equilibrium that is preferred by the good type.

23. Other models which allow for contingent control rights in venture capital contracts are Berglof (1994), Hellman (2002), and Schmidt (2003).

24. Alternatively, z could also be discrete (for example, a patent has received FDA approval or not). While we only discuss the continuous case, our results can be easily extended to discrete variables.

25. The analysis of pooling equilibria with contingent control rights is identical to the analysis of pooling equilibria with random (unconditional) control allocations and is omitted.

26. The only benefit of making W contingent on z is to reduce the need for renegotiation. If we allow for renegotiation, any contingent cash flow claim W corresponds to a non-contingent claim which yields the same expected profits to both the entrepreneur and the investor.

27. For simplicity, we do not analyze semi-separating and pooling equilibria.

28. One exception is Burkart, Panunzi, and Gromb (1997), who discuss how dispersed outside ownership deludes the real control of shareholders.

29. We omit the proof that for $\beta^s > \alpha_g$, all semi-separating equilibria with contingent control rights are pareto-dominated by at least one separating equilibrium.

Table I:

Pay-offs

	Revenues		Private Benefits
	Prob. α success	*Prob.* $1-\alpha$ failure	
a_o	1	0	Z
a_R	v	v	0

Table I summarizes the revenues and entrepreneurial private benefits of the initial project (a_o) and the same project after restructuring (a_R). α denotes the probability of success of the original project.

Table II:

Comparative statics in the separating equilibrium.

Separating Equilibrium	Formal Investor Control	Real Investor Control, (in good project)	Quality, (of average financed project)
Unobserved Project Quality Good Type	↗	↘	↗
Ex – post Uncertainty	↗	↗ or ↘	→
Entrepreneur's Stake	↘	↘	→

Table II summarizes the comparative statics results when a unique separating equilibrium exists. Observable project quality is kept fixed throughout. The unobserved project quality of a good type is a measure for the asymmetric information of the entrepreneur. Formal investor control is the right to intervene. Real investor control is the probability of actual intervention by the investor.

TABLE III:

Comparative statics in the semi-separating equilibrium.

Semi-separating Equilibrium	Formal Investor Control	Real Investor Control, (in good project)	Quality, (of average financed project)
Unobserved Project Quality Good Type	$\rightarrow$	$\rightarrow$	$\rightarrow$
Ex – post Uncertainty	$\rightarrow$	$\nearrow$	$\searrow$
Entrepreneur's Stake	$\rightarrow$	$\searrow$	$\nearrow$

Table III summarizes the comparative static results assuming a semi-separating equilibrium. Observable project quality is kept fixed throughout. The unobserved project quality of a good type is a measure for the ex ante asymmetric information of the entrepreneur. Formal investor control is the contractual right to intervene. Real investor control is the probability of actual intervention by the investor.

Figure I:

Timing

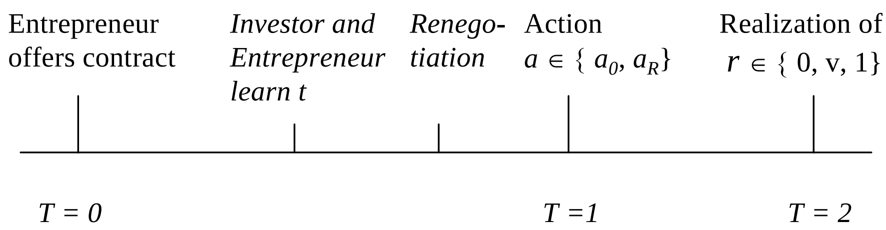

Figure 1 illustrates the timing of events. The variable $a \in \{a_o, a_R\}$ denotes the action to be taken at time $T = 1$ by either the entrepreneur or the investor, depending on who has control. The variable $r \in \{0, v, 1\}$ denotes the realized revenue at time $T = 2$.

Figure II:

Equilibria as a function of asymmetric information and co-investment.

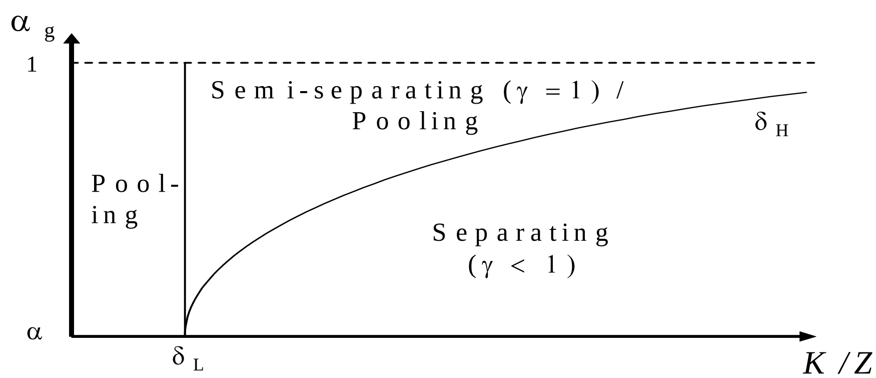

Figure 1 shows the parameter ranges for which a unique separating equilibrium exists, a semi-separating equilibrium exists, or for which only pooling equilibria exist. The variable $\gamma \in [0, 1]$ measures formal investor control, with $\gamma = 1$ denoting full investor control. On the Y-axis, α_g denotes the unobserved quality of a good project. Since observable project quality, α, is kept fixed, $\alpha_g - \alpha$ is a measure for the asymmetric information of the entrepreneur. On the X-axis, K denotes the co-investment by the entrepreneur, and Z the level of his private benefits. The parameters δ_L and δ_H are cut-off values for K/Z.