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ABSTRACT

Information and Control in Alliances and Ventures*

The allocation of control rights in a venture does not matter if partners have congruent preferences. This Paper develops a theory of control as a signal of congruence, and applies it to the structure of alliances between a privately informed 'entrepreneur' (technology firm) and an 'investor' (large corporation). Investor control increases when the entrepreneur is better informed or when the information that the investor receives during the course of the venture is more noisy. More investor control, however, often results in less investor interference, since the investor puts more trust in the entrepreneur upon receiving more control and, hence, has a tendency to neglect ambiguous information *ex post*. As a result, the cost of signaling is endogenous and the quality of the post-contracting information constrains the amount of pre-contracting information that can be revealed. Our results are in line with empirical findings on control rights in biotechnology alliances and venture capital contracts.

JEL Classification: D82, G24, G32 and L20
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1 Introduction

What drives the allocation of control rights in alliances between asymmetrically informed partners? Should control be allocated to the most informed party in order to avoid inefficiencies? Empirical evidence on technology alliances and venture capital contracts suggests the opposite: financing firms typically receive substantial control rights, whose level seems to be increasing with their informational *dis*advantage. This paper argues that a better informed 'entrepreneur' (technology firm, start-up) relinquishes control to a less informed 'investor' (large company, venture capital firm) in order to signal his *congruence.* Intuitively, an entrepreneur has not much to lose by giving up control to an investor with similar preferences. If preferences are dissonant, in contrast, the entrepreneur may refrain from this out of fear of intervention 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.

By giving up formal control rights, the entrepreneur not only obtains better contracting terms, but also gains in *informational control.*[1] Indeed, if control is a signal of congruence, then the investor puts more trust in the entrepreneur upon receiving control and, hence, has a tendency to leave the entrepreneur 'in charge' - even when she learns bad information about the latter's project. The main consequence of this is that the signalling power of control is *endogenous.* The better the entrepreneur is informed, the more the investor tends to neglect her own information and, hence, the more control rights the entrepreneur needs to give up in order to signal his congruence. It follows that *investor control is increasing in the level of asymmetric information.* Investor *interference*, in contrast, typically, decreases: while the terms of the contract allow the investor to interfer in more states of nature, she is less likely to actually use this control when bad news is revealed. Following the same logic, there is an upperbound on the information which can be signaled at the contracting stage. Indeed, a perfectly informed entrepreneur never can fully reveal that his project will be a success, as the investor then never would interfere.

One may wonder why control rights play such an important role in the ne-

[1] See Aghion and Tirole (1997) for a discussion on the distinction between formal authority, that is the right to decide, and 'informational' or 'real' authority, that is the effective control over decisions due to one's superior information.

gotiation of technology alliances and venture capital contracts.[2] Two reasons have been put forward in the literature:[3] First, following Grossman and Hart (1986) and Hart and Moore (1998), decision rights may be important for influencing relation-specific investments. Control rights are then allocated in a way 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.[4] The financial contracting literature, instead, has focused on how control rights affect the trade-off between cash-flows and private benefits. Thus, a project may yield both monetary returns that are verifiable and transferable, and private benefits which are non-verifiable and go only to the entrepreneur. As shown by Aghion and Bolton (1992), control is again optimally allocated to the entrepreneur, since the investor is a ruthless value-maximizer which neglects these private benefits. The only reason why we may observe *investor control,* according to the above theories, are *financing constraints*: whereas entrepreneur control is efficient, it may not dispense enough verifiable profits to give the investor his required rate of return.[5]

While the impact of financing constraints on control seems to be supported by the data, some empirical findings remain unexplained. Lerner and Merges (1998), analyzing 200 bio-tech alliances, find that projects in their early stages at the time of the alliance formation, assign significantly less control to the R&D firm.[6] Intuitively, these are the stages where the uncertainty and the informational asymmetries between investor and entrepreneur are most extreme. Similarly, Kaplan and Stromberg (2001) find that VCs are more likely to have board and voting control in pre-revenue ventures and in industries with a higher

[2] In bio-tech alliances the prerogatives of parties in every stage of the process are carefully delineated in the agreements, going from the allocation of research dollars, the management of clinical trials, to the ownership of patents and know-how. The financing firm may further receive the right to terminate particular projects, cancel the alliance or 'shelve' the projects, or, in contrast, to extend the breadth of the alliance by adding new technologies under development. Similarly, venture capital contracts separately allocate cash-flow rights, board rights, voting rights, liquidation rights, and other control rights.

[3] See, e.g., Hart (2000) for a more detailed discussion.

[4] Hellman (1998), in contrast, argues that investor control may be usefull since it protects the venture capitalist from hold-up by the enterpeneur when looking for a superior management team.

[5] See also Legros and Newman (2000) for a general model in which transferring authority can be used as a means to transfer surplus in the presence of liquidity constraints.

[6] 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.

volatility; in contrast, they are less likely to have voting control with repeat entrepreneurs[7] (see also Gompers (1998) for similar results). 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." Kaplan and Stromberg (2002), using direct risk-assessments in VC investment memos, provides additional strong support for this view. In this paper, we develop a rationale for why, as suggested by the above findings, the investor receives more control when the entrepreneur has more asymmetric information. Our model produces also most of the other stylized facts on venture capital contracts, such as contingent control rights and concave cash-flow claims.

Model and Results — Our analysis proceeds as follows: A technology company (the 'entrepreneur'), has an idea for a project but lacks money or complementary assets, and hence must rely on an alliance with a large company or venture capitalist (the 'investor'). The entrepreneur not only hopes to earn monetary revenues, but also derives a private benefit of undertaking and running the project. This creates a potential conflict of interest with the investor, who only cares about the verifiable returns. In particular, the returns of the project are stochastic and at an intermediate date, the project can be restructured/reoriented which reduces the riskiness of the verifiable returns, but destroys the private benefits of the entrepreneur.[8] If the investor is sufficiently pessimistic about the potential of the entrepreneur's project, she would like to restructure the project. For simplicity, we assume that intervention is always inefficient ex-post.

Central to our model is an adverse selection problem. In the absence of any asymmetric information, the entrepreneur keeps all control rights, as we assume that the expected verifiable return of the project is large enough to compensate the investor, and investor interference reduces total surplus.[9] In contrast, an asymmetrically informed entrepreneur who believes he has a successful project will try to *signal his congruence* by offering the investor (some) *control rights.* Indeed, during the course of the venture, the investor will receive (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

[7] Entrepreneurs who have founded another venture previously.

[8] Restructuring typically reduces the riskiness of the project, since it involves selling some assets, reducing the activities of the firm or even liquidating the project.

[9] This differentiates our model from Aghion-Bolton (1992).

knows that the information is likely to be favorable, this may prevent a 'bad' (dissonant) entrepreneur from seeking funding.

The *amount of control rights* which are relinquished by the entrepreneur is driven by the interplay between his ex ante asymmetric information and the information which becomes available to the investor ex post. *More control rights shift to the investor as the ex ante asymmetric information of the entrepreneur is larger.* Intuitively, by signalling his congruence, the entrepreneur increases his *informational authority* over the venture: an investor which 'trusts' the entrepreneur, will tend to neglect his own information and leave the entrepreneur in charge. As a result, the better his information, the less intervention a good type faces in a separating equilibrium, and the more control rights he needs to give up in order to distinguish himself from a bad entrepreneur. Similarly, *investor control tends to increase when the ex-post information of the investor becomes more noisy*, as the investor then puts less faith in his own information and is less inclined to intervene. If the ex-post information of the investor becomes too noisy, however, signalling congruence with control rights becomes very inefficient (the investor very often intervenes in good projects) or impossible, and a good entrepreneur may seek to signal its type using other devices.

Following the same logic, the amount of private information which the entrepreneur can signal ex ante, is constrained by the quality of the investor's information ex post. A perfectly informed entrepreneur, for example, never can fully reveal his private information. Indeed, if this were possible, the investor would always neglect his own (noisy) signal upon receiving control, and pooling would be unavoidable. More generally, the more informative the information structure ex post, the better a good type can signal his private information ex ante.

What is *more* investor control? Control is typically not an indivisible right held by either the investor or the entrepreneur, but resembles a continuous variable adjusted through contingent provisions (See Lerner-Merges and Kaplan-Stromberg). In a first step, our model captures this by allowing for a probabilistic control allocation. Such a probabilistic control allocation becomes more relevant, however, once we allow control to be made contingent on a measure of performance which is correlated with the information of the investor. As we show, control then shifts to the investor after bad performance. The larger the asymmetric information of the entrepreneur, the higher the cut-off value below which the investor receives control. Intuitively, a *contingent control allocation* improves upon a random control allocation, as it is reduces intervention in precisely those states of nature where it is most likely that the investor mistakenly intervenes in a good project. Hence, it allows to decrease the probability of intervention faced by a good entrepreneur, while keeping the threat of intervention constant for a bad type.

Finally, as long as the verifiable measure is sufficiently correlated with the information of the investor, the investor is always offered a *concave cash-flow claim,* in which she receives all the verifiable revenues in case they are low. Such a cash-flow claim increases the incentives of the investor to intervene and, hence, makes it easier to signal congruence. By minimizing the returns for the entrepreneur under intervention, it further reduces the incentives of a bad entrepreneur to pool.

Outline — This paper is organized as follows. After we discuss the related literature in section 2, section 3 outlines the model. In section 4, we characterize the equilibrium allocation of control rights under symmetric and asymmetric information. Section 5 discusses the determinants of investor control, in particular those with respect to the information structure. In section 6, we expand the contractual framework by considering contingent control rights, liquidation cash-flow rights, and other signalling devices. We summarize in section 7.

2 Related Literature

Control theories: Our model is closest related to the control theories of Aghion and Bolton (1992) and Dewatripont and Tirole (1994). As pointed out in the introduction, Aghion-Bolton provides a theory of investor control based on financing constraints. Whereas entrepreneur control is always efficient, the entrepreneur may need to give up control to the investor in order allow the latter to break even. Building on this model, Dewatripont-Tirole provides a theory of diversity of securities, where 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 debt-holders do not (they like to intervene). As in our model, poor performance is thus followed by a high probability of interference. In contrast to our model, however, asymmetric information and the distinction between formal and 'informational' control, plays no role: cash-flow claims - not information - determines whether or not a particular outside investor interferes with management.[10]

Among a number of papers which focus on control rights in venture capital contracts (see also Berglof (1994) and Hellmann (1998)), our results are most related to Kirilenko (2001). In his model, a risk-averse entrepreneur signals the profitability of his project through the number of shares offered to investors. Signal extraction is more difficult as the entrepreneur has more control, since the private benefits of control are noisy and privately known. Investor control is thus not a signal, but a necessary condition for signalling through other means to be possible. As in our model, investor control is increasing in the degree of asymmetric information. Unlike our model, however, the amount of investor control only depends on the variance in private benefits and is independent of its level. Further, investor control destroys entrepreneurial private benefits regardless of how this control is used. In this paper, investor control only hurts the entrepreneur if there is actually investor interference. This difference between 'formal' and 'informational' control, key to our results, is absent in Kirilenko.

Signalling Models: Starting with Leland and Pyle (1977), there is a huge 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 which 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.[11] It is therefore not a viable alternative to signaling with control. We do not want to claim, though, that control is the *only way* through which the entrepreneur can signal the quality of his project. Hence, Section 6.3 compares control with other signalling devices such a costly collateral or increasing once stake in the project, and discusses when control rights are likely to prevail. The signaling model which probably comes closes 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 intermedi-

[10] Theirs is further a theory of the capital structure of a publicly held company who employs an agent to run the firm. It is unclear to us how to draw implications from this for control allocations in alliances and venture-capital contracts.

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

ate date.[12] The borrower is further also 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. Finally, several papers have shown how contractual features can be used to signal private information.[13] As far as we know, however, our model is the first to point out how control may be used as a signalling device.

3 Model

Consider a young technology firm that has a novel idea, but lacks financial means and/or complementary assets (manufacturing know-how or capacity, a distribution network) 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/venture capitalist, referred to as the *investor (she),* must both commit some critical resources, whose opportunity cost we denote respectively by K and I.[14] Besides K, our entrepreneur has no wealth. We suppose 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, out of a set of available actions A, must be taken which 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, is not only interested in the impact of the actions on the verifiable returns of the project, but 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, on-the-job consumption, etc. Secondly, in *technology alliances*, part of the output of

[12] To the extent that the interim profits of the project are correlated with the ex-post information of the investor, short-term debt may also be a way of implementing an optimal contingent control allocation. See Aghion-Bolton (1992) for a similar interpretation.

[13] See, for example, Aghion-Bolton (1987), Hermalin (1988, chapter 1) and Spiers (1992).

[14] These resources could be purely financial, as in the case of a venture capitalist, or a mix of both financial and physical/human capital as is typically the case in technology alliances.

the project is often consumed internally and 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 which do not belong in the scope of the joint-venture.[15] Note that in technology alliances, also the investor may derive private benefits: certain applications of the technology may be a substitute or a complement to existing products of the investor and hence cannibalize or enhance the profits made on these products. The assets or skills of the venture may further be 'stolen' by the investor for individual use.

For simplicity, we assume that there are only two relevant actions at date $1 : a_B$ (private benefit action) and a_R (restructuring action).

(i) We denote by a_B 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_B probably requires that the entrepreneur runs the project, we assume that a_B yields a private benefit to the entrepreneur, whose monetary equivalent we denote by B, but none to the investor. The impact of a_B on the returns of the project is stochastic and depends on the state of nature $\theta \in \{\theta_b, \theta_g\}$. With a probability α, $\theta = \theta_g$ and the project provides a verifiable return at date 2 which is normalized to 1. With a probability $1 - \alpha$, $\theta = \theta_b$ and the project will fail (and have no verifiable profits). The expected revenues of a_B thus equal α.[16]

(ii) Alternatively, the project can be *re-structured/re-organized* at date 1, an action which is denoted by a_R. We assume that a_R is less risky than $a_B : a_R$ yields a lower return $v < 1$, but this in any state of nature. This reflects the fact that a reorganization typically involves (at least) partial sales of assets or reduction of activities.[17] 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

[15] 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" (p126-127).

[16] The assumption that B is independent of the state of nature is wlog. Our results would not be qualitatively affected if private benefits were larger (smaller) for $\theta = \theta_b$.

[17] With exception of the structure of cash-flow claims, our results would not be qualitatively affected if a^R was as risky as a_B, 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 $\theta = \theta_b$ (see 'information structure').

allow the investor to recoup its investment, that is $v < I$. We will allow v to be contractible, hence endogenizing the returns of intervention to the investor. In a first take, however, we will assume that v is non-verifiable and totally accrues to the investor, which simplifies the contracting problem. In a technology alliance, for example, the investor could use the assets or knowledge of the venture to foster other projects in which she is involved, or she could simply 'raid' the assets of the venture.

	Revenues		Private Benefits
	$\theta = \theta_g$ (Prob. α)	$\theta = \theta_b$ (Prob. $1 - \alpha$)	
a_B	1	0	B
a_R	v	v	0

Table 1.

To focus on asymmetric information and adverse selection as a driver of control rights, we will make the following assumptions:

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

Assumption A1 creates the adverse selection problem central to our model. Assumption $A2$ distinguishes the rationale for investor control in our model from the one developed by Aghion and Bolton (1992) and thus works *against* our main results (investor control in equilibrium). For $I < \alpha$, 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. 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 (action a_R) if she is sufficiently pessimistic about its prospects, the entrepreneur always prefers to keep the project 'going as it is' (action a_B).

Information Structure. — At date 0, the entrepreneur receives a private signal $s \in \{0, 1\}$ which is correlated with θ. We shall assume that[18]

$$\begin{aligned} \text{Prob}\,(\theta = \theta_g \mid s = 1) &\equiv \mu > \alpha \\ \text{Prob}\,(\theta = \theta_g \mid s = 0) &= 0 \end{aligned}$$

Thus, if $\mu = 1$, the entrepreneur is perfectly informed whereas if $\mu = \alpha$ he has no informational advantage over the investor.[19] Hence, $\mu - \alpha$ is a *measure of the asymmetric information* between investor and entrepreneur. If $s = 1$, we refer to the entrepreneur as 'good' or 'congruent'. If $s = 0$, we refer to the entrepreneur as 'bad' or 'dissonant'. These labels reflect the more general idea that partners in alliances tend to have similar preferences over actions when verifiable revenues are high.

As the project proceeds, more information about the project becomes available. In particular, both entrepreneur and investor observe a signal $t \in [0, 1]$ between date 0 and date 1, whose distribution we denote by $F_b(t)$ and $F_g(t)$ for $\theta = \theta_b$ and $\theta = \theta_g$ respectively (note that we assume that s and t are uncorrelated conditional on θ). The distribution of t satisfies the monotone likelihood ratio property (MLRP): $\zeta(t) \equiv f_g(t)/f_b(t)$ is increasing in t.

Contracts and Control. — At date 0, after having observed s, the entrepreneur proposes a contract to the investor. We assume that the actions are non-contractible, except for who has the authority over them.[20] 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

[18] More generally, our results would not be qualitatively affected if an enterpreneur, upon receiving a signal $s = 0$, would assign 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 λ. In a semi-separating equilibrium (see further), 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 what 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 $r = 1$.

[19] Formally, our information structure corresponds to $\text{Prob}(s = 1 \mid \theta = \theta_g) = 1$ and $\text{Prob}(s = 1 \mid \theta = \theta_b) = \beta < 1$ with $\mu = \dfrac{\alpha}{\alpha + (1 - \alpha)\beta}$.

[20] 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-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)

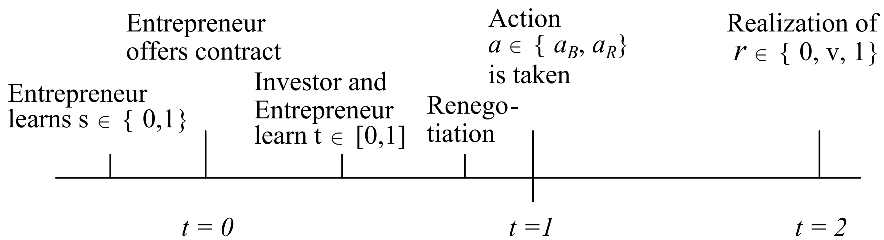

Figure 1: Timing

include all contracts specifying:

(i) A cash-flow claim (W, w) for the investor. There are three possible outcomes for the final period returns: $r \in \{1, v, 0\}$. Since the entrepreneur is wealth constraint, the contract only needs to specify a compensation $W \leq 1$ in case $r = 1$ and $w \leq v$ in case $r = v$. If v is not verifiable, this simplifies to a cash-flow claim W in case of success.

(ii) A control allocation: We denote by $\gamma \in [0, 1]$ the probability that the investor receives control over the date 1 action. In section 6.1, we will allow γ to be made contingent on a measure of performance which is correlated with t. Initially, however, we will assume that t is not verifiable. Control is typically not an indivisible right held by either the investor or the entrepreneur, but resembles a continuous variable adjusted through contingent provisions (See Lerner-Merges and Kaplan-Stromberg). A probabilistic control allocation allows us to capture this in a very parsimonious, albeit imperfect, way. Obviously, a probabilistic control allocation becomes more relevant once we allow for contingent control rights.

We denote by C the set of all possible contracts and by $c = (\gamma, W, w)$ a particular contract. 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. Therefore, we assume that once t has been learned, the entrepreneur can make a take-it-or-leave-it offer of a new contract to the investor.

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), which we will refer to as CK-equilibria.

4 Control as a signal of congruence

Intuitively, control rights in the venture are irrelevant if the preferences of the investor and entrepreneur are perfectly congruent. This suggests that an ex ante asymmetrically informed entrepreneur may use control rights to signal 'positive' private information: to the extent that the entrepreneur is confident that his project will be a success - and also the investor will prefer a_B over a_R - he has not much to lose by giving up control to the investor.

To focus our attention on control rights (rather than on cash-flow claims), this section makes the simplifying assumption that $w = v$ exogenously, that is the investor receives all the revenues in case of intervention ($a = a_R$). First, the latter assumption is reasonable in *technology alliances.* 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. Secondly, the assumption that the investor receives all of the verifiable revenues if the latter are low, is also an empirical regularity in *venture capital contracts,* as documented by Kaplan and Stromberg (2001). While this could be for unmodeled reasons (for example, to induce more effort on behalf of the entrepreneur), we will show in section 6.2 that $w = v$ typically arises endogenously in our model.

4.1 Investor behavior

Let us first characterize the date 1 behavior of an investor which has accepted a contract c at date 0. What are the incentives of the investor to intervene in equilibrium? Let $\hat{\mu}$ be the *investor's belief that the project is good upon being offered a contract c at date* 0. We have

$$\hat{\mu} \equiv \hat{\mu}(c) \in [0, \mu]$$

During the course of the venture, the investor receives a signal $t \in [0, 1]$ and updates her belief that the project is good using Bayes rules. Denoting by φ

this *updated date* 1 *belief*, we have that

$$\varphi \equiv \varphi(t, \hat{\mu}) = \frac{\hat{\mu}\zeta(t)}{\hat{\mu}\zeta(t) + (1 - \hat{\mu})}$$

In the absence of renegotiation, the investor then would like to intervene if and only if $\varphi(t, \hat{\mu})W < v$. As long as $\varphi(t, \hat{\mu}) > v$, however, the entrepreneur can offer the investor a larger cash-flow right $W' = v/\varphi(t, \hat{\mu})$, in which case the investor prefers to leave effective control to the entrepreneur (action a_B).[21] Thus, allowing for renegotiation, an investor with control will intervene if and only if

$$\varphi(t, \hat{\mu}) < v$$

From the MLRP, $\varphi(t, \hat{\mu})$ is increasing in t. Hence, there exists a *cut-off value* $t^I(\hat{\mu})$ defined by

$$\begin{aligned} \varphi(t^I(\hat{\mu}), \hat{\mu}) &= v, \\ \Leftrightarrow \quad \zeta(t^I(\hat{\mu})) &= \frac{v}{1-v}\frac{1-\hat{\mu}}{\hat{\mu}} \end{aligned} \tag{1}$$

such that the *investor will intervene if and only if* $t < t^I(\hat{\mu})$.[22] Thus, the lower $t^I(\hat{\mu})$, the larger the *informational control* of entrepreneur over the venture. Note that $t^I(\hat{\mu})$ is decreasing in $\hat{\mu}$: as the investor has more trust in the entrepreneur, she is more willing to neglect bad information about the project (low values of t) and leave the agent in charge. To make things interesting, we assume that the investor intervenes with positive probability if $\hat{\mu} = \alpha$:

- $t^I(\alpha) > 0$ (**A4**)

At date 0, the investor accepts the contract if and only if W, γ and $\hat{\mu}(c)$ are sufficiently high such that she breaks even in expectations. Under entrepreneur control, a_B is always implemented which yields a pay-off W to the investor if the project is good. Under investor control, renegotiation or intervention yields an expected pay-off of v whenever $t < t^{ren}$, where t^{ren} is defined by $\varphi(t^{ren}, \hat{\mu})W = v$. Given control rights γ and investor beliefs $\hat{\mu}(c)$, W must

[21] 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 signalling value since no new information arises.

[22] This assumes $\zeta(0) < \frac{v}{1-v}\frac{1-\hat{\alpha}}{\hat{\alpha}}$. If $\zeta(0) < \frac{v}{1-v}\frac{1-\hat{\alpha}}{\hat{\alpha}}$, we denote $t^I = 0$.

therefore satisfy the following individual rationality constraint:[23]

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

4.2 The symmetric information benchmark

Assume first that s is totally uninformative, that is the entrepreneur always receives a signal $s = 1$, from which $\mu = \alpha$. The following control allocation prevails:

Proposition 1

- *If $I < \alpha$, the entrepreneur proposes a contract with full entrepreneur control and $W = I/\alpha$*
- *If $\alpha < I < \bar{I}$, with*

$$\bar{I} \equiv \alpha\left[1 - F_g(t^I(\alpha))\right] + \left[\alpha F_g(t^I(\alpha)) + (1-\alpha)F_b(t^I(\alpha))\right]v,$$

  the entrepreneur proposes a contract specifying $\gamma^* \in (0,1)$, where γ^* is increasing in I
- *If $I > \bar{I}$, no financing is possible*

Proof. The proof is omitted. ■

Our first proposition illustrates the *'financing constraint'* rationale for investor control, as pointed out in Aghion-Bolton (1992). If the investor has control, she intervenes whenever $t < t^I(\alpha)$. A good project is then mistakenly restructured with a probability $F_g(t^I(\alpha))$. It follows that entrepreneur control is always efficient, as the latter never restructures a good project.[24] Unfortunately, if the financing capacity of the project is too small, entrepreneur control is not feasible. Indeed, when $I > \alpha$, the individual rationality constraint of the investor (IR) cannot be satisfied for $\gamma = 0$. Some control rights then need to be given to the investor. It is easy to see that γ^* will be increasing in I : more control needs to be given to the investor as the financing capacity of the project further decreases. If $I > \bar{I}$, no financing is possible.

[23] Since the pay-off of a bad type is independent of W (a bad entrepreneur knows the outcome will never be $r = 1$), any reasonable belief $\hat{\mu}(c)$ should be independent of W.

[24] This result does not depends on our assumption that $v < B$ and, hence, intervention a in bad projects is inefficient. Indeed, if $v > B$, then under entrepreneur control, renegotiation would always ensure that a project is restructured if this is ex post optimal. Investor control, in contrast, would result in excessive intervention.

4.3 Control allocations under asymmetric information

For $I < \alpha$, there is full entrepreneur control in the symmetric information benchmark. By maintaining this assumption throughout the remainder of the paper, we will focus on a rationale for investor control which purely relies on *asymmetric information* and not on the above *limited financing capacity.*

What happens if the entrepreneur has superior information, that is s is informative and, hence, $\mu > \alpha$? Let us first look for a *separating or semi-separating equilibrium* in which a good entrepreneur offers a contract c specifying a stochastic control allocation γ. In any (semi-) separating equilibrium, a bad type must not strictly prefer to mimic a good type, which will be the case is if and only if

$$\gamma * F_b \left(t^I (\hat{\mu}(c))\right) \geq F_b(t^{sp}) \tag{IC}$$

where t^{sp} is defined such that if the investor were to intervene whenever $t \leq t^{sp}$, then a bad type is indifferent between seeking funding or not:

$$[1 - F_b (t^{sp})] B = K$$

Let $\mu^{sp}(\gamma)$ then be the *belief* $\hat{\mu}$ *for which (IC) holds at the equality given a control allocation* γ. Since $t^I(\hat{\mu})$ is decreasing in $\hat{\mu}$, the incentive constraint *(IC)* will be satisfied if and only if

$$\hat{\mu} \leq \mu^{sp}(\gamma) \tag{IC$'$}$$

It further follows that $\mu^{sp}(\gamma)$ is increasing in γ. Intuitively, if the investor receives less control (γ is smaller), she must be more pessimistic about the project ($\hat{\mu}$ must be smaller) in order to sustain the same critical probability of intervention which refrains a bad entrepreneur from pooling. Abusing notation, we denote $\mu^{sp} \equiv \mu^{sp}(1)$. By definition, we have $\hat{t}(\mu^{sp}) = t^{sp}$: μ^{sp} *is the investor belief which implements the cut-off value* t^{sp}.

Lemma 1 *Equilibrium beliefs induced by a contract* c, $\hat{\mu}(c)$, *are never larger than* $\max \{\mu^{sp}, \alpha\}$.

Proof. In a pooling equilibrium, $\hat{\mu}(c) = \alpha$. In a (semi-)separating equilibrium, IC$'$ must be satisfied. ■

Proposition 2 *No separating equilibrium exist if* $\mu > \mu^{sp}$.

Proof. In a separating equilibrium, $\hat{\mu}(c^*) = \mu$, where c^* is the contract offered by a good type. Hence, if $\mu > \mu^{sp}$, then IC′ is violated. ■

Intuitively, if the entrepreneur is very well informed, that is μ is close to 1, then he cannot perfectly reveal his type by relinquishing control. Indeed, if this were possible, the investor would have a nearly blind belief in the entrepreneur, and would almost never intervene. Giving up control is then only a small sacrifice for a bad entrepreneur, and pooling is unavoidable.

More generally, lemma 1 provides us with an *upperbound on the information which a contract can signal*. As will be shown in section 5, μ^{sp} is increasing in the informativeness of the date 1 signal t : *the amount of pre-contracting private information which can be signalled, is constrained by the quality of the post-contracting information.* If t is very uninformative, μ^{sp} may be smaller than α and no information can be conveyed through the contract. In contrast, if t is very informative, then μ^{sp} will be larger than μ and a separating equilibrium exists in which all information is revealed. For intermediate values of μ^{sp}, a good entrepreneur can only partially reveal his information.

The following proposition characterizes all separating and semi-separating equilibria:

Proposition 3 *Assume* $\mu^{sp} > \alpha$:

- *If* $\mu < \mu^{sp}$, *there exists a unique, separating, CK-equilibrium in which a good entrepreneur offers a contract* c^* *which specifies date 1 investor control with a probability*

$$\gamma^* = \frac{F_b(t^{sp})}{F_b(t^I(\mu))} \tag{2}$$

- *If* $\mu > \mu^{sp}$, *there exists a semi-separating CK-equilibrium in which a good entrepreneur proposes a contract* c^* *specifying* $\gamma = 1$ *and a bad entrepreneur pools with a probability* q^* *such that*

$$\hat{\mu}(c^*) = \mu^{sp} \Leftrightarrow \frac{\alpha\mu}{\alpha + (\mu - \alpha)q^*} = \mu^{sp} \tag{3}$$

All semi-separating equilibria in which a good entrepreneur offers a contract specifying $\gamma < 1$ *are strictly pareto dominated by the above equilibrium.*

Proof. See Appendix ■

Intuitively, $\mu < \mu^{sp}$ if the entrepreneur is only *marginally better informed* than the investor (μ is close to α), or the investor receives *very good information at date* 1 (μ^{sp} is close to 1). In the above cases, the investor will not put much weight on the signal conveyed by the entrepreneur, but mainly rely on his own information in order to decide whether or not to intervene. A bad type then faces a high probability of intervention, and will prefer not to seek financing if this involves relinquishing full control to the investor. Since the investor's ex post information is noisy, however, also a good entrepreneur faces a positive (though lower) probability of intervention. He will thus prefer to minimize the amount of investor control γ subject to the incentive constraint *(IC)* of the bad type. Since $\hat{\mu}(c^*)$ is identical to μ in any separating equilibrium, this *minimum level of investor control* is given by (2). As usual, this 'least-cost' separating equilibrium, if it exists, is the unique equilibrium which satisfies Cho-Kreps 'Intuitive Criterion'.[25]

If $\mu > \mu^{sp}$, the incentive constraint of the bad entrepreneur cannot be satisfied in a separating equilibrium, as the investor then would have too much trust in the entrepreneur and neglect his own noisy information. If there exists a positive probability q that also a bad entrepreneur relinquishes control, however, 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 (IC') will be satisfied whenever a bad entrepreneur pools with a probability $q \geq q^*$, where q^* is such that $\hat{\mu}(c^*)$, the investor's belief that the project is good upon being offered a contract c^*, equals μ^{sp}. Since the equilibrium belief $\hat{\mu}(c^*)$ is determined using Bayes' rule, q^* is given by (3). It follows that for $\mu > \mu^{sp}$, there exists a semi-separating equilibrium in which a good type always offers full investor control and a bad type mimics the good type with a probability $q = q^*$.

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 $B - x\varepsilon$ with ε very small but positive and x a privately known character-

[25] In a two-type model, an equilibrium does not satisfy the 'Intuitive Criterion' if there exists an out-of-equilibrium move which 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.

istic of the entrepreneur, uniformly distributed on $[0,1]$. In a semi-separating equilibrium, only bad entrepreneurs with type $x \leq q^*$ then would seek funding.

In addition to the above semi-separating equilibrium where $\gamma = 1$, there also exist a range of semi-separating equilibria in which the entrepreneur relinquishes control with a probability $\gamma < 1$. As shown in appendix, however, these equilibria are pareto-dominated since they involve more pooling (a higher q^*) and, hence, a higher cash-flow claim needs to be given to the investor. Indeed, q^* must then be such that $\hat{\mu}(c^*) = \mu^{sp}(\gamma)$, where $\mu^{sp}(\gamma) < \mu^{sp}$. In addition, even though the investor has less control rights, a good type faces a higher probability of intervention as the investor is more eager to intervene for higher values of q^*.[26].

So far, we have shown that there exists a unique equilibrium whenever $\mu < \mu^{sp}$, and a range of semi-separating equilibria which can be pareto-ranked for $\alpha < \mu^{sp} < \mu$. In all of these equilibria, the investor receives at least some control rights, whereas under symmetric information, full entrepreneur control would prevail. If no unique equilibrium exists, it is easy to see that *pooling equilibria* in which both types relinquish some control rights $\gamma > 0$, are an alternative equilibrium prediction to semi-separating equilibria, if $\mu^{sp} \in (\alpha, \mu)$, or the only equilibrium prediction, if $\mu^{sp} < \alpha$. Also in these equilibria, however *asymmetric information results in at least some investor control:*

Proposition 4 *No CK-pooling equilibrium exists in which both types keep control ($\gamma = 0$).*

Proof. See Appendix ■

Note that only if one focuses on the CK-equilibrium where $\gamma = 1$ for $\mu > \mu^{sp}$, control rights are continuous in μ around μ^{sp}. The latter equilibrium is also the only equilibrium which satisfies Cho-Kreps (stronger) D1 criterion.[27] For our comparative static purposes, we will focus on this equilibrium.

5 Determinants of investor control

We are now ready to derive a number of comparative static results. We respectively analyze the impact of a change in the ex ante asymmetric information

[26] The bad type and the investor are indifferent between the different equilibria, since they obtain a pay-off 0 in any semi-separating equilibrium.

[27] See Fudenberg and Tirole (1991), chapter 11, for a general discussion of D1 and related equilibrium refinements in signaling equilibria.

between investor and entrepreneur, a change in the quality of the information which comes available during the course of the venture, and finally, the impact of a change in the private benefits and the pledgible resources of the entrepreneur.

5.1 Ex ante asymmetric information

Perhaps the most important testable implication of proposition 3 is that when *the entrepreneur is better informed (s is more informative)*, then *he gives up more control to the investor (*γ^* is higher) and this up to the point that no separating equilibrium exists:

Proposition 5 *For $\mu < \mu^{sp}$, investor control γ^* is strictly increasing in μ*

Proof. For $\mu < \mu^{sp}$ there exists a unique separating CK-equilibrium where a good type assigns the investor γ^* control rights where γ^* is such that IC holds at the equality:

$$\gamma^* F_b(t^I(\mu)) = F_b(t^{sp})$$

As $t^I(\mu)$ is decreasing in μ, γ^* must be increasing in μ ■

Intuitively, when the entrepreneur is better informed, the investor is more likely to neglect ambiguous information during the course of the venture and trust an entrepreneur which has signalled 'positive' private information at the contracting stage. In terms of our model, $t^I(\mu)$ is decreasing in μ. This, however, increases the incentives of a bad entrepreneur to relinquish control as well. In order to separate himself from a bad type, an entrepreneur which is confident of having a good project then needs to assign more control rights to the investor.

The positive relationship between asymmetric information and investor control is in line with empirical research on control rights in technology alliances and venture capital contracts. 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.* Firms entering into such 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. Lerner-Merges finds 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 bio-technology firm. Intuitively, these are the stages where the uncertainty and the informational asymmetries are most extreme, and the biotechnology firm is most likely to have private information concerning his own project. Similarly, Kaplan and Stromberg (2001) 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[28] 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.' Gompers (1998) finds similar results.

One short-coming of the above analyses 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 Stromberg (2002) are able to construct more precise risk measures, and distinguish between external risk (such as market size, customer adoption, competition) and internal risk (risks associated with asymmetric information about management quality and actions). They find that both an increase in internal risk and an increase in external risk are associated with significant more investor control. While it seems very likely that internal risk is subject to private information, this is perhaps more questionable for external risk. As we discuss in the next section, however, our model also predicts that investor control should be increasing in the noisiness of the post-contracting information (the variable t). Empirically, when the external environment is more uncertain, the post-contracting information of the investor is likely to be more noisy.

While a better informed entrepreneur assigns more control to the investor, this does not imply that there will also be more *investor interference* in equilibrium. Intuitively, it is precisely *because* the investor is less eager to interfere, that he receives more control rights, and thus more opportunities to interfere:

Proposition 6 *For $\mu < \mu^{sp}$, investor interference in good projects decreases as μ increases. Investor interference in bad projects remains constant.*

Proof. From (2), investor interference in a good project is given by :

$$\gamma^* F_g(t^I(\mu) = F_b(t^{sp}) \frac{F_g(t^I(\mu))}{F_b(t^I(\mu))} \quad (4)$$

[28] Entrepreneurs who have founded another venture previously.

Since from the MLRP, $F_g(t^I(\mu))/F_b(t^I(\mu))$ is increasing in $t^I(\mu)$, and $t^I(\mu)$ is decreasing in μ, it follows that (4) is decreasing μ.The fact that investor interference in bad projects remains constant stems directly from (2). ■

Thus, whereas a better informed entrepreneur relinquishes more *formal* control rights, he does have more *effective* control over the venture (he faces less intervention). It would be mistaken, though, to conclude that investor intervention is always inversely related to investor control. Indeed, as will be shown further, investor control and investor interference will be both increasing (or decreasing) in changes in other fundamentals, such as entrepreneurial private benefits and pledgible resources.

Note, finally, that the above results stand in stark contrast with *informational theories of authority and control in organizations*, which argue that control should be allocated to the best informed party (Dessein (2001)) or to the party which is in the best position to acquire information (Aghion and Tirole (1998)). The key difference is that in the above papers, there is a *predefined authority relationship*, where the uninformed party (the principal) has control, but may decide to transfer this control to the informed party (the agent). In contrast, in this paper, there is no such pre-defined relationship, and the parties must still agree whether or not to enter in a relationship and on what terms. Control may - and will - then be used as a signal of good information and good intentions by the better informed party.

5.2 Quality of ex-post information

A key premise of our model is that the informational asymmetries between investor and entrepreneur decrease during the course of the venture, as the investor receives additional information. In order to investigate the impact of an improvement in this ex post information, we first define what we understand with a better information structure. Let $F = (F_g, F_b)$ and $\hat{F} = \left(\hat{F}_g, \hat{F}_b\right)$ be two date 1 information structures and let - wlog - the scale of t under $\hat{F}$ be such that $\hat{\zeta}(t) = \hat{f}_g(t)/\hat{f}_b(t) = 1 \Leftrightarrow \zeta(t) = 1$.

Definition: $\hat{F} = \left(\hat{F}_g, \hat{F}_b\right)$ *is more informative than* $F = (F_g, F_b)$ *if* $\forall t \in (0, 1)$:

- $\hat{F}_g(t) < F_g(t) \quad \wedge \quad \hat{F}_b(t) > F_b(t)$, and
- $\hat{\zeta}(t) < \zeta(t) \Leftrightarrow \zeta(t) < 1$

While the first condition is standard,[29] the second condition requires that if a particular value of $t \in (0, 1)$ used to be 'bad' news under information structure F (the investor revises his prior downwards upon observing t), it is even worse news under information structure $\hat{F}$. Similarly, if another value of t used to be 'good' news under F, it is even better news under $\hat{F}$.

Since μ^{sp}, t^{sp} and $t^I(\mu)$ are a function of the date 1 information structure, abusing notation, we denote by $\mu^{sp}(F)$, $t^{sp}(F)$ and $t^I(\mu, F)$ respectively their value for a particular information structure F. The following result holds:

Lemma 2 *If $\hat{F}$ is more informative than F then (i) $t^I(\mu, \hat{F}) > t^I(\mu, F)$, (ii) $t^{sp}(\hat{F}) < t^{sp}(F)$ and (iii) $\mu^{sp}(\hat{F}) > \mu^{sp}(F)$ if $\mu^{sp}(F) > \alpha$.*

Proof. See Appendix ■

By increasing $t^I(\mu)$, a better date 1 information structure thus relaxes the incentive constraint of the bad type, which requires that $\gamma F_b(t^I(\mu)) \geq (B-K)/B$. In addition, by increasing μ^{sp}, a better information structure also increases the maximal amount of private information which can be signalled at the contracting date. Indeed, together with Proposition 2, lemma 2 implies that

Corollary 1 *An increase in the informativeness of the post-contracting information, increases the maximum level of confidence, $\hat{\mu}(c^*)$, which can be signalled at the contracting stage.*

Consider two information structures F and $\hat{F}$, where $\hat{F}$ is more informative than F. Whenever a unique separating equilibrium exists, we denote by $\gamma^*(F)$ and $\gamma^*(\hat{F})$ the equilibrium control allocation given F, respectively $\hat{F}$. The following proposition then shows that the level of *investor control decreases as t becomes more informative*:

Proposition 7 *If a unique separating equilibrium exists for F, then there also exists a separating equilibrium under $\hat{F}$, and $\gamma^*(\hat{F}) < \gamma^*(F)$.*

Proof. The first half of the claim stems directly from lemma 2, (iii). Suppose now that a separating equilibrium exists for both F and $\hat{F}$. By definition of t^{sp}, $F_b(t^{sp}(F)) = \hat{F}_b(t^{sp}(\hat{F}))$, and thus from (2), $\gamma^*(\hat{F}) * \hat{F}_b(t^I(\mu, \hat{F})) = \gamma^*(F) *$

[29] Note that whenever $\hat{F}_g(t)/\hat{F}_b(t) < F_g(t)/F_b(t)$ holds for any $t \in (0, 1)$, then by simply rescaling t under information structure $\hat{F}$, one can always ensure that this first condition is satisfied (without affecting the second condition).

$F_b(t^I(\mu, F))$. From lemma 2, $t^I(\mu, \hat{F}) > t^I(\mu, F)$. As $\hat{F}_b(t) > F_b(t)$ for any t, it follows that $\gamma^*(\hat{F}) < \gamma^*(F)$. ■

Intuitively, if the quality of the post-contracting information deteriorates, the probability that a bad project goes 'undetected' increases. A larger amount of investor control is then necessary to deter a bad type from seeking financing. As noted previously, Kaplan-Stromberg's finding that more external uncertainty is associated with more investor control provides some support for this prediction. Indeed, the post-contracting information of the investor is likely to be more noisy as the general uncertainty surrounding the project increases.

As we argue in section 6.3, however, if the post-contracting information becomes too noisy, signalling congruence using control rights becomes very inefficient (as too much good projects are terminated) and may even be impossible. A good entrepreneur may then prefer to use other devices to signal his type.

5.3 Pledgible resources and private benefits

To conclude, we have a look at two other, potentially measurable, determinants of control: the level of private benefits of the entrepreneur (the parameter B) and his pledgible resources or stake in the venture (parameter K):

Proposition 8

- *γ^* is strictly increasing in B/K as long as $\mu^{sp} > \mu$*
- *μ^{sp} is decreasing in B/K; an increase in B/K may thus result in a shift from an equilibrium contract where $\gamma^* < 1$ to one where $\gamma^* = 1$*

Proof. We have $[1 - F_b(t^{sp})] B = K$, from which t^{sp} is increasing in B/K and, since $t^I(\mu^{sp}) = t^{sp}$, μ^{sp} is decreasing in B/K. As $\gamma^* F_b(t^{sp}) = F_b\left(t^I(\mu)\right)$ for $\mu < \mu^{sp}$, where $t^I(\mu)$ is independent of B/K, it follows that also γ^* is increasing in B/K for $\mu < \mu^{sp}$. ■

The logic behind proposition 8 is straightforward: the larger the ratio B/K, the more eager is a bad type to find financing and the less he has to loose by giving up control. An entrepreneur which is confident of having a good project then needs to give up more control in order to signal his type.

A prediction of our model is thus that the investor will receive less control as the financial resources of the entrepreneur increase, which is one of the main findings in Lerner-Merges (1998). This prediction seems further consistent with the finding in Kaplan-Stromberg (2001) that repeat entrepreneurs receive more control rights, as the latter are likely to have more financial resources to invest in the venture.

Proposition 8 allows us to relax the assumption that the entrepreneur *must* invest all his resources in the project: 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* $K < B$. Indeed, a larger K reduces the amount of control rights which needs to be given to the investor, hence avoiding inefficient intervention.

Remark, finally, that the impact of B/K is quite different from that of an increase in μ. An increase in μ results in more investor control, but less investor *interference* in equilibrium. In contrast, a reduction in K (or an increase in B) results both in an increase of investor control *and* in an increase in investor interference.[30]

6 Expanding the contractual framework

Thus far, we have analyzed a world in which the contracting instruments were limited to a cash-flow claim W and a stochastic control allocation γ. We now extend our analysis (i) by allowing for control rights to be *contingent* on some verifiable measure of performance, (ii) by allowing the liquidation or restructuring cash-flow v to be contractible, and (iii) by providing the entrepreneur with other ways through which he can signal his confidence, such as investing a larger amount of his resources into the venture.

6.1 Contingent control rights

One of the findings of Kaplan and Stromberg (2001) 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

[30] As $t^I(\mu)$ is independent of B/K, and γ^* is increasing in B/K, both $\gamma^* F_g(t^I(\mu))$ and $\gamma^* F_b(t^I(\mu))$ are increasing B/K.

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. For concreteness, we assume $z \equiv t + \eta$, where $\eta \sim \mathcal{N}(0, \sigma^2)$ independently from θ.[31] The noise η stands for all the information learned by the investor during the course of the venture which 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 $t^I(\mu)$, 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 $t < t^I(\mu)$. 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

$$\Pr(t + \eta \leq z^c, t \leq t^I(\mu) \mid \theta = \theta_b) = F_b(t^{sp}) \tag{5}$$

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 Stromberg (2001), we thus fund 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 (5), since $t^I(\mu)$ is decreasing in μ, we have that z^c is increasing in μ : 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 B/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.[32] We

[31] 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.

[32] The analysis of pooling equilibria with contigent control rights is identical to the analysis of pooling equilibria with random (unconditional) control allocations and is omitted.

summarize in the next proposition.

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

- *If $\mu^{sp} > \mu$, there exists a unique, separating, equilibrium in which a good entrepreneur offers a contract specifying*

$$\begin{aligned} \gamma(z) &= 1 \quad \text{for all } z \leq z^c \\ \gamma(z) &= 0 \quad \text{for all } z > z^c \end{aligned}$$

  where z^c, given by (5), is (i) increasing in μ, with $\lim_{\mu \to \mu^{sp}} z^c = +\infty$, (ii) decreasing in the informativeness of $F(t)$, (iii) increasing in B/K

- *If $\mu^{sp} \in (\alpha, \mu)$, 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 the good type, from which W cannot be used as a signalling device.[33]

6.2 Liquidation cash-flow claims

VC contracts almost always have a debt-like feature in which the VC's cash-flow claim is senior to the common stock claims of the founders for an amount which is at least as large the investor's initial investment.[34] In particular, it is noteworthy that this feature does not vary with the uncertainty of the venture. When the value of the venture is low, the VC then receives the full value of the venture, which is consistent with our assumption that v fully accrues to the investor in case of a restructuring or a liquidation.

While the above empirical regularity could be rationalized by forces outside our model (for example, the need to induce more effort on behalf of the entrepreneur), we now show that, typically, such a debt-like cash-flow claim also arises endogenously in our model. Let us therefore assume that the returns

[33] 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.

[34] In Kaplan-Stromberg (2001) this was true for all but one of the financing.

to intervention v are contractible. The offered contract then must specify, in addition to γ and W, a cash flow return $w \in [0, v]$ in case revenues equal v. If the equilibrium contract gives the investor a *concave cash-flow claim* where she receives the totality of the verifiable profits if the latter are small ($w = v$), but only a fraction $W < 1$ if profits are large, then the outcome is identical as in our previous analysis. We maintain the assumption, made in the previous section, that there exists a contractible variable $z \equiv t + \eta$ on which control rights can be made contingent. The following result holds:

Proposition 10

- *If $\mu^{sp} \in (\alpha, \mu)$, all semi-separating equilibria in which a good entrepreneur offers a contract specifying $w < v$, are strictly pareto-dominated by the semi-separating equilibrium in which a good entrepreneur offers a contract specifying $\gamma = 1$ and $w = v$.*
- *If $\mu^{sp} > \mu$, then if $\sigma(\eta)$ is sufficiently small, there exists a unique, separating, equilibrium in which a good type offers a contract specifying $w = v$ and contingent control rights $\gamma(z)$ as in Prop. 9.*

Proof. See Appendix ■

Intuitively, there are two effects of setting $w < v$. On the one hand, reducing w, *increases the incentives of a bad type to seek funding* for a given level of intervention. On the other hand, reducing w also *reduces the incentives of the investor to intervene.* In terms of our model, $t^{sp}(\gamma, w)$, the intervention threshold needed to prevent a bad entrepreneur from pooling given γ, is given by

$$(1 - \gamma F_b(t^{sp}))B + \gamma F_b(t^{sp})\,(v - w) = K$$

and is a *decreasing* function of w. In contrast, the threshold below which the investor effectively intervenes, $t^I \equiv t^I(\hat{\mu}, w)$, is given by

$$\zeta(t^I) = \frac{w}{1 - w}\frac{1 - \hat{\mu}}{\hat{\mu}}$$

and is *increasing* in w. Incentive compatibility requires $t^I(\hat{\mu}, w) \geq t^{sp}(\gamma, w)$ and is thus more difficult to achieve for $w < v$.

It is now easy to see that a concave cash-flow claim ($w = v$) is unambiguously good if there is *not enough intervention* in equilibrium, that is $\mu^{sp} \in (\alpha, \mu)$ and only semi-separating equilibria exist.[35] Indeed, by increasing the incentives

[35] The analysis of pooling equilibria with $w < v$ is almost identical to the analysis of pooling equilibria where $w = v$ and is omitted.

of the investor to intervene for a given level of pooling and by reducing the incentives of bad types to pool for a given level of intervention, the level of bad types which seek financing in equilibrium is minimized. As pooling by bad types destroys total surplus, setting $w = v$ must therefore increase the average monetary pay-off of a good type. A good type, however, could still be worse off by setting $w = v$ if this would imply that he faces a higher probability of intervention. In appendix, however, we show that a good type faces *less intervention* for $w = v$, as the lower level of pooling reduces the eagerness with which the investor intervenes in equilibrium.

Things are different when $\mu^{sp} > \mu$ and a separating equilibrium exists. If $\gamma = 1$, then there is *too much intervention* in equilibrium (IC is not binding). The entrepreneur then has *two instruments to reduce intervention* by the investor. One way is to give the investor less control. Another way is to reduce the investor's incentives to intervene by lowering her cash-flow claim w in case revenues equal v. The advantage of using the cash-flow claim to reduce intervention is that it is *selective*: there is less intervention exactly in these states of nature close to $t(\hat{\mu}, w)$ where the investor is most likely to mistakenly intervene in a good project. The disadvantage of offering a less concave cash-flow claim, however, is that it also increases the incentives of a bad entrepreneur to seek funding: t^{sp} is increasing in w, which makes it harder to satisfy IC. It follows that if z is sufficiently correlated with t, it is better to use contingent control rights to selectively reduce intervention, since the latter method does not affect IC. Hence $w = v$ is optimal. In contrast, if z in not sufficiently correlated with t, our results are ambiguous. Compared to an unconditional control restriction γ and $w = v$, setting $w < v$ and $\gamma = 1$ *increases the level of intervention which is needed* to prevent pooling , but this level will be achieved *more efficiently.* Both $w < v$ and $w = v$ may be optimal, depending on parameter values. In Appendix, we give an example of both cases and derive a sufficient condition for $w = v$ to be optimal even when z is uncorrelated with t. In these examples, our comparative static results with respect μ continue to hold, even when $w < v$.

6.3 Control rights versus other signalling devices

When an entrepreneur seeks financing for a project or a bio-tech company seeks a partner to form an alliance, there may exist other ways through which congruence can be signalled. What determines then the attractiveness of control as a signalling device?

To focus ideas, let us assume that, in addition to K, the entrepreneur *may invest another asset into the venture*, which reduces the investment needed from the investor by A, but whose opportunity cost equals $(1+\phi)A$, with $\phi > 0$. We make the following two additional assumption:

Assumption 5.1: $B - K \leq A < I$

Assumption 5.2: $\phi A < \frac{(\mu - \alpha)}{\alpha} I$

From assumption 5.1, there always exists a separating equilibrium in which a good type invests his assets A in the venture and a bad type seeks no financing. The expected utility of a good type in this '*asset separating equilibrium*' is given by

$$\mu + B - \phi A - I \tag{6}$$

From assumption 5.2, the expected utility of a good entrepreneur is higher in this separating equilibrium than in any pooling equilibrium.

The entrepreneur, however, may also relinquish control rights to signal his type. Let us assume, for simplicity, that $\gamma \in [0, 1]$ can be made contingent on t and that $B = v$ (intervention in bad projects is welfare neutral). If $\mu^{sp} > \mu$, a separating equilibrium exists in which a good type relinquishes control to the investor contingent on $t \leq t^{sp}$. The expected utility of a good type in this equilibrium is given by

$$\mu(1 - F_g(t^{sp})) + B - I \tag{7}$$

If $\mu^{sp} \in [\alpha, \mu]$, a semi-separating equilibrium exists in which a good type fully relinquishes control and a bad type pools with some probability. The expected utility of a good type in this equilibrium can be shown to be

$$\mu(1 - F_g(t^{sp})) + B - \frac{\mu}{\mu^{sp}} I + \left[\mu \frac{(1 - \mu^{sp})}{\mu^{sp}} - (1 - \mu) \right] F_b(t^{sp}) B \tag{8}$$

Note that since $B = v < I$, the last two terms in this expression are increasing in μ^{sp} and smaller than $-I$ for $\mu^{sp} < \mu$. This reflects the fact that in a semi-separating equilibrium, a good type must cross-subsidize bad types in order to allow the investor to break even.

Given assumption 5.1 and 5.2, if (6) is larger than (7) or, for $\mu^{sp} < \mu$, if (6) is larger than (8), then a good type obtains a higher pay-off by investing

$K + A$ into the venture - hence credibly revealing his type - than in any other equilibrium. As a result, 'signalling with assets' is the unique equilibrium which satisfies Cho-Kreps intuitive criterion. In contrast, if (7) is larger than (6) and $\mu^{sp} > \mu$, 'signalling with contingent control rights' is the unique CK-equilibrium. If $\mu^{sp} \in [\alpha, \mu]$ and (8) is larger than (6), signalling with control rights is the pareto-dominant CK-equilibrium.

It is now interesting to see how *a change in the quality of the investor's ex-post information* affects the use of control as a signalling device. From lemma 2, a better information structure decreases t^{sp} and $F_g(t^{sp})$, resulting in an increase of (7), the expected utility of a good type in the separating equilibrium. Similarly, if $\mu^{sp} \in [\alpha, \mu]$, a better information structure increases μ^{sp} and, hence, reduces the amount of pooling in the pareto-dominant semi-separating equilibrium. Thus, also (8) is increasing in the quality of the investor's ex-post information.[36]

Fact If $\mu^{sp} > \alpha$, an increase in the informativeness of the ex-post information structure may shift the unique or pareto-dominant CK-equilibrium from one in which a good type signals his congruence using assets to one in which he uses control rights, but never the other way round.

Intuitively, if the investor can better distinguish between good and bad projects ex post, then she will intervene less in good projects for a given level of intervention in bad projects. Since the latter level is fixed in any (semi-)separating equilibrium, a better ex-post information structure makes signalling using control rights more efficient. Note further that as the investor's ex post information becomes perfect, $F_g(t^{sp})$ goes to zero and μ^{sp} goes to one, such that signalling with control rights always dominates signalling with assets. In contrast, when the investor's ex-post information becomes sufficiently noisy, the investor never intervenes such that signalling using control rights is impossible.

The previous analysis shows that there is a limit to the result of Section 5.2 that a more noisy ex-post information structure results in more investor control. *If the ex-post information of the investor becomes too noisy, the entrepreneur may refrain from using control as a signalling device, as it becomes very inefficient or ineffective.* The above results further highlight the important *informational role* of *venture capitalists.* When the investor receives better information

[36] By definition of t^{sp}, $F_b(t^{sp})$ remains constant.

during the course of the venture, relinquishing control rights is less costly to the entrepreneur, improving the efficiency of the venture. A rather straightforward extension of our model would be to endogenize this ex post information, allowing venture capitalists to add value (and earn profits) as superior monitors or information collectors.

7 Conclusion

This paper has developed a theory of the structure of alliances between an 'entrepreneur' and an 'investor', in which asymmetric information is the main driver of control allocations. We have shown that even a small amount of asymmetric information results in a substantial shift of control to the initially uninformed investor as the entrepreneur wants to signal his congruence. Investor control is further increasing in the level of informational asymmetries (both ex ante and ex post), decreasing in the resources of the entrepreneur, and is optimally made contingent on verifiable measures of performance, with control shifting to the investor after bad performance. These results stand in sharp contrast with theories of control in organizations, which typically argue that decision rights should be allocated to the best informed party.[37]

From an empirical point of view, the above results are consistent with the fact that investor control is very prevalent in technology alliances and venture capital contracts, as compared to other, more traditional, financing arrangements. Indeed, the projects undertaken by start-ups and technology companies such as bio-tech firms are typically surrounded by substantial informational asymmetries. Also *among* technology alliances and venture capital financing, however, we see a substantial heterogeneity in the allocation of control. In line with our predictions, empirical research by Lerner and Merges (1998) and Kaplan and Stromberg (2001,2002) show that the pharmaceutical company, respectively the venture capitalist is assigned more control when the potential informational asymmetry is larger. Other predictions of our model, such as contingent control rights and the structure of cash-flow rights, are also in line with stylized facts on venture capital contracts.

Our model can be improved or extended in a number of directions. Perhaps the biggest short-coming of our model is that we only consider *'first round'*

[37] See Aghion-Tirole (1997) and Dessein (2001).

financing, and it is not clear how our results carry over to later financing rounds. An interesting extension would be to consider a model in which the investor receives new information at several intermediate dates. A key question is then whether all the signalling will take place during the first round, or whether the entrepreneur should gradually relinquish more control over time, depending on the information which is gradually revealed to the investor. On another level, we have confined the analysis to ventures between an investor and an entrepreneur, and equated congruence with the quality of the project. As is clear from our analysis, however, control can in principal be used as a signal of congruence in *any* joint-venture. Congruence of preferences will then be related to dimensions which are often unrelated to the quality of the project. Indeed, the output of a joint-venture is often consumed internally, in which case the 'private benefits' of a project are much more important than its monetary returns. By giving up more formal control rights, a better informed partner may then gain in trust and informational authority, and increase its actual influence over the venture's actions.

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8 Appendix

8.1 Signaling congruence through control rights

Proof of Proposition 3: *(i) A unique separating CK-equilibrium for $\mu < \mu^{sp}$.* In any separating Perfect Bayesian Equilibrium (PBE), a good type must offer a contract $c = \{\gamma, W\}$ where γ and W are such that IC is satisfied, that is

$$\gamma \geq \gamma^* \equiv F_b(t^{sp})/F_b(t^I(\mu)),$$

and *(IR)* is satisfied. Whenever, $\mu \leq \mu^{sp}$, $t^I(\mu) \geq t^{sp} \equiv t^I(\mu^{sp})$ and thus $\gamma^* \leq 1$. Similarly, since $I < \alpha$ and $\hat{\mu}(c) = \mu$ in a separating equilibrium, for any γ, there always exists a $W^*(\gamma) < 1$ for which (IR) holds a the equality. For $\mu < \mu^{sp}$, there exists thus a range of separating PBE where $\gamma \geq \gamma^*$ and $W \geq W^*(\gamma)$ and hence both (IC) and (IR) are satisfied. However, only the separating PBE which maximizes the expected utility of the good type among all separating PBE will survive the intuitive criterion (the argument is standard and is omitted). Obviously, in this 'least-cost' separating equilibrium, IR must hold at the equality, that is $W = W^*(\gamma)$. We now show that $\gamma = \gamma^*$ in this equilibrium. Given $W = W^*(\gamma)$, the expected utility of the good entrepreneur in a separating equilibrium is given by

$$\mu(1 - \gamma F_g(t^I(\mu))) \left[B + 1 - \bar{W}\right] + (1 - \mu) \left[1 - \gamma F_b \left(t^I(\mu)\right)\right] B \tag{9}$$

where $\bar{W}$ denotes the *expected return to the investor* for $r = 1$ given a binding IR constraint:[38]

$$\begin{aligned} I &= \mu(1 - \gamma F_g(t^I(\mu)))\bar{W} + \left[\mu\gamma F_g(t^I(\mu)) + (1 - \mu)\gamma F_b(t^I(\mu))\right] v \\ \Leftrightarrow \quad \bar{W} &= \frac{I - \left[\mu\gamma F_g(t^I(\mu)) + (1 - \mu)\gamma F_b\left(t^I(\mu)\right)\right] v}{\mu(1 - \gamma F_g\left(t^I(\mu)\right))} \end{aligned}$$

Hence, (9) can be rewritten as

$$\mu(B+1) - I - \mu\gamma F_g(t^I(\mu)) \left[1 + B - v\right] + (1-\mu) \left[B - \gamma F_b\left(t^I(\mu)\right)(B - v)\right]. \tag{10}$$

Since (10) is decreasing in γ, the only separating equilibrium which satisfies the intuitive criterion is the one where $\gamma = \gamma^*$ and $W = W^*(\gamma)$. 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 $\mu < \mu^{sp}$, is given after we characterize all semi-separating

[38] Note that $\bar{W}$ is higher than the return W specified in the initial contract: whenever t is such that $\varphi(t, \mu)W < v \leq \varphi(t, \mu)$, the initial contract will be renegotiated to a higher return $W' = v/\varphi(t, \mu)$ to avoid (inefficient) intervention by the investor.

CK equilibria for $\mu > \mu^{sp}$.

(ii) *Semi-separating equilibria:*

If $\mu^{sp} < \mu$, no separating equilibrium exist. We now show that for $\mu^{sp} \in [\alpha, \mu]$, there exists a range of semi-separating equilibria which can be pareto-ranked, and in which a good entrepreneur offers a contract c specifying $\gamma \leq 1$ and a bad type pools with a probability q^*. If $\mu^{sp} < \alpha$, no semi-separating equilibrium exist. If $\mu^{sp} > \mu$, semi-separating equilibria exist, but they do not satisfy the intuitive criterion.

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

$$\hat{\mu}(c) = \frac{\alpha\mu}{\alpha + (\mu - \alpha)q^*} \in [\alpha, \mu]$$

Since a bad type must be indifferent between pooling and obtaining no financing, q^* must be such that $\hat{\mu}(c) = \mu^{sp}(\gamma)$ and hence (IC) is binding. Since $\mu^{sp}(\gamma)$ is increasing in γ and $\mu^{sp}(1) \equiv \mu^{sp}$, whenever $\mu^{sp} \in [\alpha, \mu]$, there exists a range of semi-separating equilibria in which a good type offers a contract specifying $\gamma > \gamma'$ with $\mu^{sp}(\gamma') = \alpha$. No semi-separating equilibrium exists if $\mu^{sp} < \alpha$. If $\mu^{sp} > \mu$, a range of semi-separating equilibria exist where $\gamma \in (\gamma', \gamma'')$ with $\mu^{sp}(\gamma'') = \mu$.

Intuitive Criterion: Any semi-separating equilibrium in which a good type offers a contract specifying $\hat{\gamma} > \gamma'$ can be supported by investor beliefs $\hat{\mu}(c) = 0$ if $\gamma < \hat{\gamma}$ and $\hat{\mu}(c) = \mu^{sp}(\gamma)$ if $\gamma \geq \hat{\gamma}$. Whenever $\mu^{sp} \in [\alpha, \mu]$, these beliefs satisfy the 'Intuitive Criterion'. Indeed, since a bad type obtains a pay-off of 0 in equilibrium, by definition of μ^{sp}, he would strictly prefer to relinquish more control rights if this were to fool the investor that he was a good type. As a result, a good type cannot credibly signal his type - and break the equilibrium - by offering more control rights than specified in the equilibrium.

Expected Utility: We now calculate the expected utility of a good type in a semi-separating equilibrium and show that

(i) this expected utility is increasing in γ; hence, for $\mu^{sp} < \mu$, the equilibrium with $\gamma = 1$ pareto-dominates all other semi-separating equilibria.

(ii) for $\mu^{sp} > \mu$, a good type obtains a higher utility in the least-cost separating equilibrium; hence no semi-separating equilibrium survives the intuitive criterion for $\mu^{sp} > \mu$.

As $\hat{\mu}(c) = \mu^{sp}(\gamma)$ in a semi-separating equilibrium, the investor would like to intervene if and only if $t < t^{sp}(\gamma) \equiv t^I(\mu^{sp}(\gamma))$. As the IC constraint is binding in equilibrium, we have

$$\gamma F_b(t^{sp}(\gamma)) = F_b(t^{sp})$$

The expected utility of a good entrepreneur is thus given by

$$U_g^{ss}(\gamma) = \mu(1-\gamma F_g(t^{sp}(\gamma)))\left[B+1-\bar{W}\right] + (1-\mu)(1-F_b(t^{sp}))B$$

where $\bar{W}$ is given by:

$$I = \mu^{sp}(\gamma)(1-\gamma F_g(t^{sp}(\gamma))\bar{W} + \left[\mu^{sp}(\gamma)\gamma F_g(t^{sp}(\gamma)) + (1-\mu^{sp}(\gamma))F_b(t^{sp})\right]v$$

Substituting $\bar{W}$ and γ and rearranging some terms, this yields

$$\begin{aligned} U_g^{ss}(\gamma) &= \mu(B+1) - \mu F_b(t^{sp})\frac{F_g(t^{sp}(\gamma))}{F_b(t^{sp}(\gamma))}\left[1+B-v\right] \\ &\quad + (1-\mu)(1-F_b(t^{sp}))B - \mu I - \mu\frac{(1-\mu^{sp}(\gamma))}{\mu^{sp}(\gamma)}\left[I - F_b(t^{sp})v\right] \end{aligned}$$

(i) From the MLRP, $F_g(t)/F_b(t)$ is increasing in t. Since $t^{sp}(\gamma)$ is decreasing in γ, then also $F_g(t^{sp}(\gamma))/F_b(t^{sp}(\gamma))$ is decreasing in γ. It follows that the second term of $U_g^{ss}(\gamma)$ is increasing in γ [this reflects that a good project faces a lower probability of intervention as γ increases]. Since $\mu^{sp}(\gamma)$ is increasing in γ, also the last term of $U_g^{ss}(\gamma)$ is increasing in γ [this reflects that for a higher γ, there is less pooling and hence $\bar{W}$ is smaller]. As all other terms are independent of γ, $U_g^{ss}(\gamma)$ is increasing in γ and for $\mu^{sp} \in [\alpha, \mu]$, the semi-separating equilibrium in which $\gamma = 1$ pareto-dominates all other semi-separating equilibria.
(ii) From (10), if $\mu^{sp} > \mu$, the expected utility of a good type in the least-cost separating equilibrium where $\gamma = F_g(t^I(\mu))/F_b(t^I(\mu))$, can be rewritten as

$$\begin{aligned} &\mu(B+1) - \mu F_b(t^{sp})\frac{F_g(t^I(\mu))}{F_b(t^I(\mu))}\left[1+B-v\right] \\ &+ (1-\mu)\left[1-F_b(t^{sp})\right]B - \mu I - \mu\frac{(1-\mu)}{\mu}\left[I - F_b(t^{sp})v\right] \end{aligned}$$

From the MLRP, $F_g(t)/F_b(t)$ is increasing in t. Since for $\mu < \mu^{sp}$, $t^I(\mu) < t^{sp} \leq t^{sp}(\gamma)$ and in any semi-separating equilibrium $\mu^{sp}(\gamma) \in [\alpha, \mu]$, it follows that this expression is larger than $U_g^{ss}(\gamma)$. Hence, for $\mu^{sp} > \mu$, no semi-separating equilibrium satisfies the intuitive criterion: provided that his would reveal his type, a good type strictly prefers to offer the investor $\gamma^* + \varepsilon$ control rights, whereas from (IC), this move is strictly dominated for a bad type regardless of the beliefs of the investor. ■

Proof of Proposition 4: 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 $\mu^{sp} \leq \alpha$ and γ' is defined by $\mu^{sp}(\gamma') = \alpha$ for $\mu^{sp} > \alpha$. 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

$$\gamma^p F_b(t^I(\alpha)) = F_b(t^I(\mu)),$$

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

$$\tilde{\gamma} F_b(t^I(\alpha)) = \gamma^d F_b(t^I(\mu))$$

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

$$\gamma^d F_g(t^I(\mu)) = \tilde{\gamma} F_b(t^I(\alpha)) \frac{F_g(t^I(\mu))}{F_b(t^I(\mu))} < \tilde{\gamma} F_g(t^I(\alpha))$$

Following the logic of the Intuitive Criterion, the investor must therefore place a probability 1 to 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 $\hat{\mu}(c) = 0$ if $\gamma < \tilde{\gamma}$ and $\hat{\mu}(c) = \alpha$ if $\gamma \geq \tilde{\gamma}$. These beliefs satisfy the intuitive criterion, since also a bad type would optimally make an out-of-equilibrium move in which he relinquishes full control, provided that this move would fool the investor in believing him to be a good type. ■

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 of by 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 $\gamma = 1$. ■

8.2 Determinants of investor control: Lemma 2

(i) Let us denote by t^ζ the value of t for which $\zeta(t) = 1$. We have that $\varphi(t^\zeta, \mu) = \mu$ and $\varphi(t^I(\mu), \mu) = v$. Since $\mu > \alpha$ and, by assumption, $\alpha > v$, we must have that $t^I(\mu) < t^\zeta$ and thus

$$\hat{\zeta}(t^I(\mu, F)) < \zeta(t^I(\mu, F)) = \frac{v}{1-v} \frac{1-\mu}{\mu}$$

Since also

$$\hat{\zeta}(t^I(\mu,\hat{F})) = \frac{v}{1-v}\frac{1-\mu}{\mu}$$

it follows from the MLRP that $t^I(\mu,\hat{F}) > t^I(\mu,F))$

(ii) By definition,

$$\hat{F}_b(t^{sp}(F)) \geq F_b(t^{sp}(F)) = 1 - K/B$$

Since also $\hat{F}_b(t^{sp}(\hat{F})) = 1 - K/B$, it must be that $t^{sp}(\hat{F}) < t^{sp}(F)$.

(iii) If $\mu^{sp}(F) > \alpha$, then also $\mu^{sp}(F) > v$ and thus

$$\zeta(t^{sp}(F)) = \frac{v}{1-v}\frac{1-\mu^{sp}(F)}{\mu^{sp}(F)} < 1$$

from which $t^{sp}(F) < t^{\zeta}$. By definition, it follows that $\zeta(t^{sp}(F)) > \hat{\zeta}(t^{sp}(F))$ and thus, from (ii) and the MLRP,

$$\zeta(t^{sp}(F)) > \hat{\zeta}(t^{sp}(\hat{F}))$$

Since $\mu^{sp}(F)$ is decreasing in $\zeta(t^{sp}(F))$, it follows that $\mu^{sp}(F) < \mu^{sp}(\hat{F})$. ■

8.3 Expanding the contractual framework

Contingent Control rights: Proof of proposition 9: (i) $\mu \in (\alpha, \mu^{sp})$: The characterized separating equilibrium is an equilibrium: from condition (5), the investor is able and willing to intervene with a probability $F_b(t^{sp})$ such that the IC of a bad type is satisfied. 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.[39]

Since the incentive constraint of a bad type fixes the probability of intervention in bad projects, a separating equilibrium will be preferred over another one 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

$$\gamma^* F_g(t^I(\mu)) > E\left[\Pr(t+\eta \leq z^c, t \leq t^I(\mu) \mid \theta = \theta_g)\right] \tag{11}$$

where expectations are taken over η. Since $\gamma^* = F_b(t^{sp})/F_b(t^I(\mu))$ and

$$\Pr(t+\eta \leq z^c, t \leq t^I(\mu) \mid \theta = \theta_b) = F_b(t^{sp}),$$

[39] We omit the proof that for $\mu^{sp} > \mu$, any semi-separating equilibrium with contingent control rights is dominated by at least one separating equilibrium and hence does not satisfy the intuitive criterion. The proof is similar to the one given in section 8.1.

(11) is equivalent to

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

which will be satisfied if and only if

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

Finally, the latter condition will be satisfied if

$$\forall \eta \in \left(z^c - t^I(\mu), z^c\right) : \frac{F_b(z^c - \eta)}{F_b(t^I(\mu))} > \frac{F_g(z^c - \eta)}{F_g(t^I(\mu))}$$

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

(ii) For $\mu^{sp} \in [\alpha, \mu]$, 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 $\hat{\mu}(c) < \mu^{sp}$. Indeed, suppose that $\hat{\mu}(c) = \mu^{sp}$, then a bad type would face intervention with a probability $\gamma(z)$ whenever $t < t^I(\mu^{sp}) = t^{sp}$. Since $\gamma(z) < 1$ and $t < t^{sp}$ with positive probability, this probability of intervention would be smaller than $F_b(t^{sp})$ 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 $\hat{\mu}(c) < \mu^{sp}$. In the same way as for semi-separating equilibria where $\gamma < 1$ and $\mu^{sp}(\gamma) < \mu^{sp}$, 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 $\hat{\mu}(c) = \mu^{sp}$.

(iii) *Comparative static results for* $\mu^{sp} > \mu$: We must show that z^c , given by

$$\Pr(t + \eta \leq z^c, t \leq t^I(\mu) \mid \theta = \theta_b) = F_b(t^{sp}) \tag{12}$$

is increasing in μ, with $\lim_{\mu \to \mu^{sp}} z^c = +\infty$, decreasing in the informativeness of $F(t)$, and increasing in B/K.

a) As $t^I(\mu)$ is decreasing in μ and $t^I(\mu^{sp}) = t^{sp}$, it follows from (12) that z^c is increasing in μ and $\lim_{\mu \to \mu^{sp}} z^c = +\infty$

b) We can rewrite the left-hand side of (12) as

$$E\left[F_b(z^c - \eta)\right] * F_b(t^I(\mu)$$

Consider now a more informative information structure $\hat{F}$. We show that $z^c(\hat{F}) < z^c(F)$. By definition of t^{sp}, one must have that $F_b(t^{sp}(F)) = \hat{F}_b(t^{sp}(\hat{F}))$. Hence,

$$E\left[F_b(z^c(F) - \eta)\right] * F_b(t^I(\mu, F) = E\left[\hat{F}_b(z^c(\hat{F}) - \eta)\right] * \hat{F}_b(t^I(\mu, \hat{F})$$

From lemma 2, $t^I(\mu, F) < t^I(\mu, \hat{F})$. Moreover, for any t, we have that $\hat{F}_b(t) > F_b(t)$. Hence $\hat{F}_b(t^I(\mu, \hat{F})) > F_b(t^I(\mu, F))$ and thus necessarily

$$E\left[\hat{F}_b(z^c(\hat{F}) - \eta)\right] < E\left[F_b(z^c(F) - \eta)\right]$$

from which $z^c(\hat{F}) < z^c(F)$.

c) Since t^{sp} is given by $F_b(t^{sp}) = 1 - K/B$, it follows that t^{sp} is decreasing in K/B. Since $t^I(\mu)$ is independent of K/B, from (12), z^c is decreasing in K/B. ■

Liquidation cash-flow claims: Proof of Proposition 10: We define $t^{sp}(\gamma(z), w)$ by

$$E\left[(1 - \gamma(z)F_b(t^{sp}))B + \gamma(z)F_b(t^{sp})(v - w)\right] = K \tag{13}$$

and $\mu^{sp}(\gamma(z), w)$ by $t^I(\mu^{sp}(\gamma(z), w), w) = t^{sp}(\gamma(z), w)$. Abusing notation, we denote $t^{sp}(w) \equiv t^{sp}(1, w)$ and $\mu^{sp}(w) \equiv \mu^{sp}(1, w)$. Given control rights $\gamma(z)$ and a cash-flow claim w, the incentive constraint of a bad type can be rewritten as $t^I(\mu, w) \geq t^{sp}(\gamma(z), w)$ or still as

$$\mu^{sp}(\gamma(z), w) \geq \mu. \tag{14}$$

(i) $\mu^{sp} \in (\alpha, \mu)$: We only compare semi-separating equilibria where $\gamma = 1$ and $w \leq v$. It is straightforward to show (see proof of proposition 2) that semi-separating equilibria with $\gamma < 1$ are pareto-dominated by those with $\gamma = 1$. We show that expected profits of the good entrepreneur are maximal in the semi-separating equilibria where $w = v$. Expected profits in a semi-separating equilibrium with $\gamma = 1$ and $w \leq v$ are given by

$$\begin{aligned} U_g^{ss} &= \mu(1 - F_g(t^{sp}(w)))\left[1 - \bar{W} + B\right] + (1 - \mu)(1 - F_b(t^{sp}(w)))B \\ &\quad + (v - w)\left[\mu F_g(t^{sp}(w)) + (1 - \mu)F_b(t^{sp}(w)\right] \end{aligned}$$

where $\bar{W}$ is given by the IR of the investor:

$$I = \mu^{sp}(w)(1 - F_g(t^{sp}(w)))\bar{W} + \left[\mu^{sp}(w)F_g(t^{sp}(w)) + (1 - \mu^{sp}(w))F_b(t^{sp}(w))\right]w$$

Hence, the expected utility of the good entrepreneur becomes

$$\begin{aligned} U_g^{ss}(w) &= \mu(B+1) - \frac{\mu}{\mu^{sp}(w)} I - \mu F_g(t^{sp}(w)) [1+B-w] \\ &+ (1-\mu)(1-F_b(t^{sp}(w)))B + \mu \frac{(1-\mu^{sp}(w))}{\mu^{sp}(w)} F_b(t^{sp}(w))w \\ &+ (v-w) [\mu F_g(t^{sp}(w)) + (1-\mu) F_b(t^{sp}(w)] \end{aligned}$$

Using (13), this can be rewritten as

$$\begin{aligned} U_g^{ss}(w) &= \mu(B+1) - \mu F_g(t^{sp}(w)) [1+B-v] + (1-\mu)K \\ &- \mu I - \mu \frac{(1-\mu^{sp}(w))}{\mu^{sp}(w)} [I - F_b(t^{sp}(w))w] \end{aligned}$$

where

$$F_b(t^{sp}(w))w = \frac{B-K}{B-[v-w]} w$$

is increasing in w. From (13), $\mu^{sp}(w)$ is increasing in w and $t^{sp}(w)$ is decreasing in w. It follows that $U_g^{ss}(w)$ is increasing in w and maximized for $w = v$.

(ii) $\mu^{sp} > \mu$ and $z = t + \eta$ contractible: Define w' by $\mu^{sp}(w') = \mu$. If and only if $w > w'$, there exists a separating PBE in which (i) a good type offers a cash-flow rights w in case $r = v$ and (ii) contingent control rights $\gamma(z)$ where $\gamma(z) = 1$ if $z \leq z^c(w)$ and $\gamma(t) = 0$ if $z > z^c(w)$, with $z^c(w)$ given by

$$\Pr(t + \eta \leq z^c(w), t \leq t^I(\mu, w) \mid \theta = \theta_b) = F_b(t^{sp}(w)) \tag{15}$$

Indeed, if $w < w'$ then $\mu^{sp}(w) < \mu$. Since $\mu^{sp}(\gamma(z), w) \leq \mu^{sp}(w)$ for any $\gamma(z)$, (14) is then violated. For $w > w'$, there always exists a $z^c(w)$ such that (15) holds, and hence the IC of a bad type is satisfied.

Let us denote by $U_g^s(w)$ the expected utility of a good type in the above separating equilibrium. For any $w > w'$, one can show that any separating equilibrium where the investor offers the same cash-flow claim w in case $r = v$, but specifies a different control allocation, yields a lower expected utility to the good type than $U_g^s(w)$ (the proof is similar to that of Proposition *9).* We now show that $U_g^s(w)$ is increasing in w for $\sigma(\eta)$ small and, hence, only the separating equilibrium with $w = v$ and contingent control rights $\gamma(z)$ defined as above, satisfies the intuitive criterion. Defining

$$\begin{aligned} G_g(z^c(w)) &= \Pr(t + \eta \leq z^c(w), t \leq t^I(\mu, w) \mid \theta = \theta_g) \\ G_b(z^c(w)) &= \Pr(t + \eta \leq z^c(w), t \leq t^I(\mu, w) \mid \theta = \theta_b) \end{aligned}$$

we have that

$$\begin{aligned} U_g^s(w) &= \mu(1 - G_g(z^c(w))) \left[B + 1 - \bar{W}\right] + (1-\mu)(1 - G_b(z^c(w)))B \\ &+ [\mu G_g(z^c(w)) + (1-\mu) G_b(z^c(w))] (v - w), \end{aligned}$$

where $\bar{W}$ is given by the IR constraint of the investor

$$\begin{aligned} I &= \mu(1-G_g(z^c(w)))p_H\bar{W} \\ &\quad + [\mu G_g(z^c(w)) + (1-\mu)G_b(z^c(w))]\, w \end{aligned}$$

Substituting $\bar{W}$, we have

$$\begin{aligned} U_g^s(w) &= \mu(B+1) - I + (1-\mu)\left[G_b\left(z^c(w)\right)v + \left(1-G_b\left(z^c(w)\right)\right)B\right] \\ &\quad -\mu G_g\left(z^c(w)\right)[1+B-v] \end{aligned}$$

From (15), $G_b(z^c(w)) = F_b(t^{sp}(w))$. Since $t^{sp}(w)$ is decreasing in w, also $G_b(z^c(w))$ is decreasing in w. Since $t^I(\mu,w)$ is increasing in w and $F_b(t^{sp}(w))$ is decreasing in w, from (15), $z^c(w)$ must be strictly decreasing in w for any value of $\sigma(\eta) \geq 0$. For $\sigma(\eta) = 0$, from $G_b(z^c(w)) = F_b(t^{sp}(w))$, we have that $z^c(w) = t^{sp}(w) < t^I(\mu,w)$. It follows that for $\sigma(\eta) = 0$, $G_g\left(z^c(w)\right)$ is strictly decreasing in w. By continuity, $G_g\left(z^c(w)\right)$ will also be decreasing in w for $\sigma(\eta)$ sufficiently small, from which $U_g^s(w)$ must then be increasing in w. Since both $G_g\left(z^c(w)\right)$ and $G_b(z^c(w))$ are then decreasing in w, $U_g^s(w)$ must be increasing in w and is maximized for $w = v$. ■

Liquidation cash-flow claims: z uncorrelated with t : If z is uncorrelated with t, a sufficient condition for the existence of a unique equilibrium with $w^* = v$, is that for $w < v$, a good project faces a larger probability of intervention than for $w = v$, where the amount investor control γ^* given w minimizes the probability of intervention subject to IC:

$$\gamma^* = \frac{F_b(t^{sp}(w))}{F_b(t^I(\mu,w))}$$

where $t^{sp}(w) \equiv t^{sp}(1,w)$. It follows that $w = v$ minimizes the probability of intervention in a good project if

$$\forall w \in [\tilde{w}, v) : D_w\left[F_g(t^I(\mu,w))\frac{F_b(t^{sp}(w))}{F_b(t^I(\mu,w))}\right] < 0 \qquad (16)$$

where the term in brackets denotes the probability of intervention in a good project, and $\tilde{w}$ is given by

$$t^I(\mu,\tilde{w}) = t^{sp}(\tilde{w})$$

For $w < \tilde{w}$, the incentive constraint of the bad type is always violated. Thus, (16) is a sufficient condition for $w = v$ to be optimal. If (16) is not satisfied, there may exists an (unique) equilibrium in which the entrepreneur offers a contract specifying $\gamma = 1$ and $w = \tilde{w} < v$. We give an example of both cases:

Example 1: Assume $v = B$, $f_b(t) = 1$ and $f_g(t) = 2t$. Then $F_b(t) = t$, $F_g(t) = t^2$ and $\zeta(t) = 2t$. From

$$\zeta(t^I(\hat{\mu}, w)) = \frac{w}{1-w}\frac{1-\mu}{\mu}$$

we have that

$$t^I(\mu, w) = \frac{w}{2(1-w)}\frac{1-\mu}{\mu}$$

Moreover, since $B = v$, $F_b(t^{sp}(w)) = (B-K)/w$. Given a cash flow claim w and a corresponding optimal control allocation $\gamma^*(w)$, a good project faces intervention with a probability

$$F_b(t^{sp}(w))\frac{F_g(t^I(\mu, w))}{F_b(t^I(\mu, w))} = \frac{1}{2}\frac{B-K}{1-w}\frac{1-\mu}{\mu}$$

which is increasing in w. From $B = v$, the probability of intervention in bad projects does not affect the expected utility of a good entrepreneur. It follows that there exists a unique equilibrium in which the good entrepreneur offers a contract $(w, \gamma) = (\tilde{w}, 1)$, where $\tilde{w}$ is given by $t^I(\mu, \tilde{w}) = t^{sp}(\tilde{w})$.

Example 2 : Assume $v = B$, $f_b(t) = 2-2t$ and $f_g(t) = 1$. Then $F_b(t) = 2t - t^2$, $F_g(t) = t$ and $\zeta(t) = 1/(2(1-t))$. We have

$$t^I(\mu, w) = \frac{2w - \mu w - \mu}{2w(1-\mu)}$$

such that

$$\frac{F_g(t^I(w, \mu))}{F_b(t^I(w, \mu))} = \frac{1}{2 - t^I(w, \mu)} = \frac{2w(1-\mu)}{2w - 3w\mu + \mu}$$

and thus

$$F_b(t^{sp}(w))\frac{F_g(t^I(w, \mu))}{F_b(t^I(w, \mu))} = \frac{2(B-K)(1-\mu)}{2w - 3w\mu + \mu} \tag{17}$$

which is decreasing in w for $\mu < 2/3$. Thus, if $\mu < 2/3$, (16) is satisfied and, hence, if $\mu^{sp} > \mu$, a unique CK separating equilibrium exists with $w^* = v$ and $\gamma = \gamma^* < 1$. In contrast, if $\mu > 2/3$ and $\mu^{sp} > \mu$,[40] $w = \tilde{w} < v$ and $\gamma^* = 1$. Note that the comparative statics with respect to μ continue to hold in this example: γ is increasing in μ. ■

[40] μ^{sp} is defined by $t^I(\mu^{sp}, v) = t^{sp}(v)$

$$\Leftrightarrow \frac{2v - \mu v - \mu}{2v(1-\mu)} = 1 - \sqrt{\left(\frac{w-(B-K)}{w}\right)}$$

Hence

$$\mu^{sp} = \frac{2v}{(1-v)\sqrt{\left(\frac{v}{v-B+K}\right)} + 2v}$$