Start-up finance, monitoring and collusion

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Abstract

I examine optimal financial contracts between entrepreneurs, financial intermediaries (venture capitalists) and other investors, which allocate both cashflow rights and control rights to (a) motivate the venture capitalist to monitor effectively the entrepreneur; (b) ensure that the efficient decision is taken at the interim stage concerning project continuation and refinancing; and (c) deter collusion between the entrepreneur and the venture capitalist at the expense of the other investors. The combination of asymmetric information at the interim stage with the possibility of collusion yields optimal (collusion-proof) contracts that are consistent with several commonly observed characteristics of venture capital financing.

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1. Introduction

The role of large investors as monitors has received considerable attention in the existing theoretical and empirical literature on corporate finance. Much of this attention has focused on the case of large public companies, where there may be substantial gains from having a large shareholder who engages in active monitoring, thereby reducing the scope for opportunistic behaviour by management (Shleifer and Vishny (1986)). However, ownership concentration also has costs, including the possibility that large shareholders may themselves pursue private benefits at the expense of minority shareholders.[1] Private benefits are then likely to be shared between management and block shareholders - effectively a form of collusion - as suggested by some evidence.[2]

This naturally raises the question: how does ownership structure and more generally the allocation of control rights and cashflow rights affect incentives to monitor versus incentives to collude and pursue private benefits? This question is equally important when we consider the case of entrepreneurial start-ups, which are the main focus of the present paper. Here too the monitoring role of investors such as banks and especially venture capitalists has received a great deal of attention in the literature.[3] Moreover, there could in principle be plenty of scope for collusion between venture capitalists and entrepreneurs, at the expense of other investors. There are several possible interpretations of "other investors" in this context. First, the other investors can be interpreted as the limited partners in a venture capital fund. Typically, these investors provide the bulk of the fund's capital, but they do not engage in active monitoring of the portfolio companies and are "uninformed" relative to the venture capitalist. A second possible interpretation of the "other investors" is that they represent non-venture investors, who also generally do not engage in active monitoring.[4] A third possible interpretation is that of new investors who acquire a stake in the company when it is taken public, and who will be less informed at this stage about the company than the venture capitalist who has been closely involved with the company from the start.

[1] Evidence of large shareholders obtaining private benefits of control at the expense of minority shareholders is available for the USA (Barclay and Holderness (1989)), Sweden (Bergström and Rydqvist (1990)), and Italy (Zingales (1994)).

[2] See, for example, Brickley, Lease and Smith (1988), Pagano and Röell (1998), and Pound (1988). For a theoretical analysis of collusion between management and dominant shareholders at the expense of small shareholders see Maug (2002).

[3] See, for example, Freixas and Rochet (1997) on banks and Gompers and Lerner (1999) and Kaplan and Strömberg (2003) on venture capitalists.

[4] The involvement of nonventure investors in the financing of venture-backed companies is well documented: see, for example, Gompers and Lerner (1999).

These different interpretations of the "other investors" suggest different possible forms of collusion at different stages in the company's lifecycle. As will become clear below, these collusion possibilities are closely interrelated and need to be taken into account in the design of optimal contracts. The paper therefore develops a model of entrepreneurial finance in which collusion may occur, in principle, at two different stages. Ex ante, when the financial intermediary (venture capitalist) is needed to engage in active monitoring of the entrepreneur, the two may collude so that the venture capitalist does not monitor (thereby saving the effort cost of monitoring) and, as a consequence, the entrepreneur chooses an "inefficient" project that generates significant private benefits. Ex post, when the entrepreneur and the venture capitalist learn some (private) information about the project's likelihood of success, they may collude to ensure the project is continued (which requires further financing) even though it would be efficient to liquidate. Such collusive side-agreements would typically entail some form of transfer from the entrepreneur to the venture capitalist. This is unlikely to occur through straightforward cash transfers (partly because the entrepreneur is by assumption, cash-constrained, and partly because such bribes would be easy to detect). Instead, the entrepreneur could allow the venture capitalist to gain from taking (influencing) certain decisions (for example, concerning supplier contracts or the recruitment of key employees).[5] More generally, the entrepreneur could generate benefits for the venture capitalist in a variety of ways by using corporate resources, including ideas, knowledge and information.

The fact that entrepreneurs and venture capitalists *could* find ways of colluding, to the detriment of the other investors, has important implications for the design of financial contracts.[6] Under the informational assumptions that seem to correspond most closely to the context of venture capital financing, I find that optimal *collusion-proof* contracts can take a very simple form, with the following properties:

- the allocation of *cashflow rights* to the intermediary can be interpreted as a convertible security (for example, convertible debt or preferred stock), or as

[5]There is plenty of empirical evidence showing that venture capitalists play a very active role in negotiating with suppliers, recruiting senior management, and providing entrepreneurs with access to consultants, investment bankers and lawyers (see Gompers and Lerner (1999), Hellmann and Puri (2002), Kaplan and Strömberg (2003), and Sahlman (1990)). What has not been noted is that this form of involvement by venture capitalists could, in principle, facilitate collusion between entrepreneurs and venture capitalists.

[6]Of course, reputational concerns may help to mitigate the incentives to collude. But it is unlikely that reputational concerns alone could be a sufficient deterrent (see section 3 below for a fuller discussion). To the extent that reputational effects are not sufficient by themselves, the allocation of cashflow rights and control rights matters, and the qualitative results obtained in this paper continue to hold.

a combination of debt and equity (but not straight debt or straight equity);

- *control rights* over the decision to continue or liquidate the project are given to the intermediary.

This result depends crucially on two assumptions. First, that the intermediary's monitoring skills are relatively scarce in the economy - the relative scarcity of venture capitalists' skills and expertise seems well-established. Second, that it would be possible, albeit costly perhaps, for the entrepreneur and the intermediary to collude at the expense of other investors. The result can clearly be applied, therefore, if we interpret the intermediary as a venture capitalist. It is not applicable, on the other hand, to the case of "business angels" who finance entrepreneurial start-ups out of their own capital, without raising finance from other investors.[7] This is consistent with the empirical evidence (discussed in section 4) showing that venture capitalists tend to be given predominantly convertible debt or convertible preferred stock, while business angels generally hold common stock.

An important feature of optimal collusion-proof contracts is that they give the intermediary both the *power* and the *incentives* to take the efficient continuation decision. This is done through the allocation of both cashflow rights and control rights. As noted above, the cashflow rights can be interpreted as a convertible security: in this interpretation, the intermediary's decision to exercise the conversion option acts as a credible signal to potential new investors that the firm's prospects are "good". This is consistent with the empirical evidence suggesting that venture capitalists play an important certification role (see the discussion in section 4 below). Moreover, the control rights in the optimal contract enable the intermediary to force liquidation if he wishes: this is consistent with the widespread use of redemption rights in venture capital contracts (discussed in detail in section 4).

It seems therefore that the framework developed in this paper can account for a number of commonly observed characteristics of venture capital financing. To my mind, the paper's main contribution lies in the fact that it is the first paper (to my knowledge) which takes explicit account of the relationship between entrepreneurs, venture capitalists and other investors, and the potential for collusion between entrepreneurs and venture capitalists, to the detriment of the other investors. Indeed, this is what drives the key results: the main features which correspond to observed characteristics of venture capital financing emerge in this framework as an optimal response to the threat of collusion between entrepreneurs and venture capitalists, which therefore does not occur in equilibrium.

The paper is clearly related to two broad strands of the existing literature. First, the literature on collusion in the presence of three-tier hierarchies (principal

[7] I am grateful to Alex Gümbel for drawing my attention to this point.

- supervisor - agent).[8] This literature has assumed risk aversion, transactions costs of collusion or asymmetric information within the supervisor-agent coalition in order to have a role for the supervisor (monitor). In the context of financial intermediation, the present paper identifies a fourth reason for such a role, despite the possibility of collusion : simply put, the monitor (intermediary) contributes his own capital to the venture ex ante, thereby paying for (part of) the ex-post rents he has to be given in order to deter collusion. The agency problem is therefore alleviated by bringing the monitor on board.

Secondly, the present paper is obviously related to the very large literature on venture capital;[9] the closest papers to mine are perhaps the following. Casamatta (2003) obtains different implications for the form of optimal contracts between an entrepreneur and a financier, depending on whether the financier is a venture capitalist or a business angel. In her model, the difference stems from the different magnitude of investments (venture capitalists are assumed to invest higher amounts than business angels), rather than from the fact that business angels, unlike venture capitalists, invest their own capital, without raising substantial amounts from other investors. The two models therefore yield different predictions; in particular, my model predicts, in contrast to hers, that the contracts used by venture capitalists may well differ from those used by business angels even if they invest similar amounts. Cestone (2000) and Hellmann (2000) address, as I do, the allocation of cashflow rights *and* control rights; each of these papers focuses on a quite different set of issues, and in this sense can be viewed as complementary to mine.[10]

The plan of the paper is as follows. Section 2 presents the model; section 3 examines the benchmark case of symmetric information at the interim stage, while section 4 analyses optimal contracts under asymmetric information and discusses their relation to venture capital contracts. Section 5 concludes.

[8] See Laffont and Rochet (1997) and Tirole (1992) for surveys of the theory of collusion in organisations.

[9] On the use of convertible securities in venture capital financing see, among others, Bergemann and Hege (1998), Berglof (1994), Cornelli and Yosha (2003), Repullo and Suarez (1999), and Schmidt (2003), as well as the papers referred to in the main text. On control rights see Hellmann (1998).

[10] Cestone (2000) focuses on the potential trade-off between the need to encourage entrepreneurial initiative in the early stages of a venture and the need to elicit the venture capitalist's support (help and advice) in later stages. Hellmann (2000) examines the optimal allocation of cashflow rights and control rights between entrepreneurs and venture capitalists when there is ex-ante uncertainty as to whether exit should eventually occur through an acquisition or an IPO.

2. The model

The model extends and modifies the basic model introduced by Holmström and Tirole (1997). It has two periods and three dates, t=0,1,2. There are three types of agent: entrepreneurs, monitors (intermediaries) and investors. At the beginning of the first period, t=0, each entrepreneur decides whether to invest in a project, which requires an initial expenditure equal to $C_{0.}$ At the end of the first period, t=1, the state γ is realised. If the project is continued, it requires further financing equal to C_1 and will yield return $R > 0$ at t=2 with probability γ and zero otherwise. Alternatively, the project can be liquidated at t=1, yielding liquidation proceeds of L. The entrepreneur can raise finance from monitors (intermediaries) and/or investors. All agents in the model are assumed to be risk neutral; entrepreneurs and intermediaries are protected by limited liability.

2.1. Entrepreneurs

There is a continuum of entrepreneurs of unit mass. At t=0, each entrepreneur (henceforth also called a firm) is endowed with own capital $A_f < C_0$, and an investment opportunity or idea. Entrepreneurs differ only by having different amounts of own capital at t=0. Entrepreneurial capital is distributed according to the cumulative distribution function $G(A)$, which denotes the fraction of entrepreneurs with capital less than A. The aggregate amount of entrepreneurial capital is $K_f = \int AdG(A)$.

Each entrepreneur faces considerable uncertainty about his project's returns at t=0: some of the uncertainty is resolved at t=1, when the state γ is realised. For simplicity, γ is assumed to take one of two values: γ_G ("good" state) or γ_B ("bad" state), with $\gamma_G > \gamma_B > 0$. If the project is continued, it will yield returns R at t=2 with probability γ, and zero otherwise. Thus γ represents the probability of success in the second period. Returns are assumed to be verifiable. The state γ is observed by the entrepreneur; different assumptions will be made about its observability by other agents as the analysis proceeds.

The entrepreneur can affect the probability of the good ($\gamma = \gamma_G$) or bad ($\gamma = \gamma_B$) state occurring. Specifically, he can undertake some action(s) yielding an additional private benefit B in the first period; the cost of this is to reduce the probability of the good state. A moral hazard problem may then arise when the project requires external finance. We can formalise the entrepreneur's decision as a choice between two projects: the "good" project, in which the good state will occur with probability p_H , and the "bad" project, in which the good state occurs with a lower probability p_L , but the entrepreneur receives the private benefit $B > 0$ during the first period. In what follows I denote by $\Delta p = p_H - p_L > 0$ the increase in the probability of the good state occurring associated with choosing the good project, and by $\Delta\gamma = \gamma_G - \gamma_B > 0$ the difference in the probability of success between the good state and the bad state.

2.2. Intermediaries (Monitors)

The crucial function of intermediaries in this model is monitoring, which can alleviate the moral hazard problem associated with the entrepreneur's project choice. Monitoring enables an intermediary to reduce the scope for opportunistic behaviour by the entrepreneur. I model this formally by assuming that, through monitoring, the intermediary can reduce the entrepreneur's private benefit from undertaking the bad project to b, where $B > b > 0$. This effectively reduces the entrepreneur's opportunity cost of "good behaviour". There is plenty of evidence of intensive monitoring by intermediaries such as venture capitalists: according to Gorman and Sahlman (1989), lead venture investors visit each portfolio company an average of 19 times per year, and spend 100 hours in direct contact (on site or by phone) with the company. Close involvement by venture capitalists also entails, in many cases, the provision of valuable services to the portfolio company: Sahlman (1990) notes that venture capitalists help recruit and compensate key individuals, work with suppliers and customers, and help establish tactics and strategy. This too can be interpreted as another way of reducing the entrepreneur's opportunity cost of good behaviour.

The intermediary has to incur a private cost $c > 0$ in order to monitor a project. Monitoring is assumed to be non-contractable; it will therefore only take place if the intermediary is given appropriate incentives to monitor. I shall follow Holmström and Tirole (1997) in assuming that the projects funded by an intermediary are perfectly correlated. As they argue, perfect correlation is an unrealistic but convenient simplifying assumption. The key point is that without any correlation and without diseconomies of scale in monitoring (i.e. every project costs c to monitor, regardless of the number of projects the intermediary invests in), an intermediary could, through diversification, commit to monitoring without needing to inject his own capital into the projects (Diamond, 1984). I rule out this possibility because I am interested in studying how financial contract design is affected when intermediary capital is in scarce supply (implying that intermediaries specialise in monitoring): I therefore need a model in which the amount of intermediary capital available in the economy matters.

Some degree of project correlation is in fact a much more plausible assumption than no project correlation, for a number of reasons, including the possibility of macroeconomic, industry- or sector-specific shocks, particularly for intermediaries whose monitoring skills lead to specialisation in dealing with certain industries or sectors (e.g. venture capitalists). The assumption of perfect correlation is extreme, but it simplifies the analysis. In particular, it means that we can focus on studying individual contracts between the entrepreneur and an intermediary, without modelling explicitly the intermediary's other investments, since there are no gains from cross-pledging the returns from different projects.

I shall denote by α the gross expected rate of return (per period), net of monitoring costs, demanded by intermediaries at t=0. The equilibrium value of α will be determined by the interaction between supply and demand for intermediary capital. K_m will represent the aggregate amount of intermediary capital.

2.3. Investors

In contrast to intermediaries (monitors), other investors are assumed to be too small to monitor (they also typically lack the necessary skills). For this reason, they shall generally be referred to as "uninformed investors". Investors demand a gross expected rate of return per period equal to ∂, which is normalised to one. There are many uninformed investors in each period, so that it is always possible for the entrepreneur to raise finance from uninformed investors as long as he can credibly promise them the required rate of return, $\partial = 1$.

2.4. The projects

The following assumptions will be made about the projects. Firstly, continuation is efficient at t=1 in the good state:

(A1) $\gamma_G R - C_1 > L$

Secondly, liquidation is efficient at t=1 in the bad state:

(A2) $\gamma_B R - C_1 < L$

Thirdly, it is efficient to invest in the good project ex ante, even if it requires monitoring:

(A3) $p_H(\gamma_G R - C_1) + (1 - p_H)L \geq C_0 + c$

Finally, it is never efficient to invest in the bad project:

(A4) $B + p_L(\gamma_G R - C_1) + (1 - p_L)L < C_0$

These assumptions mean that, if the entrepreneur could finance the project entirely out of own capital, he would choose the good project at t=0, continue it at t=1 if $\gamma = \gamma_G$, and liquidate at t=1 if $\gamma = \gamma_B$. In what follows, the analysis will focus on how these "first-best" choices may be induced even when the entrepreneur is capital-constrained.

2.5. Information

I shall consider two different informational assumptions concerning the state, γ, at t=1. In section 3, as a benchmark case, I assume that the realisation of γ is observed by all agents at t=1. In section 4, I focus on the case where the entrepreneur and the intermediary observe γ at t=1 but outside investors do not (as in, for example, Admati and Pfleiderer (1994), Rajan (1992) and Schmidt (2003)).

2.6. Time line

$t = 0$	$t = 1$	$t = 2$
Financial contracts signed. Monitoring? Entrepreneur chooses good or bad project.	Realisation of γ. Decision to continue or liquidate.	Project returns realised.

3. Symmetric information about γ: firm prospects at t=1 are publicly observable

This section assumes that the realisation of the state γ at t=1 is publicly observable and contractable. In particular, contracting parties at t=0 can agree that the project will be continued at t=1 if and only if the firm's prospects are good ($\gamma = \gamma_G$), thereby ensuring ex post efficiency. Since this removes any potential moral hazard problem associated with the continuation decision, financing possibilities for this case depend only on ex ante moral hazard (the moral hazard associated with the entrepreneur's project choice and the intermediary's monitoring decision). As a benchmark, we consider first the case where the possibility of collusion is ruled out a priori : that is, optimal contracts between entrepreneurs, intermediaries and investors do not need to take into account the possibility of (secret) side agreements between some of the contracting parties. The results for this case are simply the two-period analogue of those obtained by Holmström and Tirole (1997), and are described by Proposition 1 below.

Financing possibilities are determined by the extent to which the entrepreneur is capital-constrained, relative to two (endogenous) threshold levels. It is useful to define the threshold levels here :

$$A^* \equiv C_0 - L - p_H[\gamma_G R - C_1 - L - (B/\Delta p)]$$

$$A^{**}(\alpha) \equiv C_0 - L - p_H[\gamma_G R - C_1 - L - ((b+c)/\Delta p)] - cp_L/\alpha^2 \Delta p$$

We can now state :
all proofs are in the Appendix.

Proposition 1. (a) (direct finance) When $A_f \geq A^*$, the entrepreneur undertakes the good project, raising all the required external finance from uninformed investors.

(b) (mixed finance) When $A^* > A_f \geq A^{**}(\alpha)$, the entrepreneur undertakes the good project by turning to an intermediary, who will engage in (costly) monitoring.

(c) (binding financial constraint) When $A_f < A^{**}(\alpha)$, the entrepreneur does not undertake any project.

The intuition for this result is as follows. To ensure that the entrepreneur chooses the good project (which has a higher probability of success, but lower private benefits), he must be given a sufficiently large share of the project's value when it is successful. This share is denoted R_f. The project income that can be pledged to uninformed investors is therefore equal to the residual share $R - R_f$, together with the full value of liquidation proceeds L in the event of liquidation. This puts a bound on the maximum amount of external finance that can be raised from uninformed investors, given by the investors' break-even constraint. If the entrepreneur does not have sufficient own capital to make up the shortfall between this maximum amount of external finance and the required expenditure for the project, the investment cannot be undertaken relying only on direct finance (i.e. without monitoring). It may then be possible to finance the project by turning to an intermediary: monitoring reduces the entrepreneur's opportunity cost of choosing the good project, and hence reduces the share of returns that has to be pledged to the entrepreneur to satisfy his incentive compatibility constraint.

Obviously this will improve financing possibilities relative to the no-monitoring case only if monitoring services are not too costly. The cost of monitoring services depends on two things: firstly, the cost c incurred by the intermediary when he monitors, for which he has to be compensated; secondly, the difference between the rate of return demanded by intermediaries in equilibrium, α, and the rate of return demanded by uninformed investors, equal to one. Specifically, it follows from Proposition 1 that monitoring will be valuable (i.e. $A^{**}(\alpha) < A^*$) if and only if:

(A5) $\quad p_H(B - b) - c[p_H - (p_L/\alpha^2)] > 0$

In what follows I rule out the less interesting case when monitoring services are too costly, and assume that condition (A5) holds.

The equilibrium expected rate of return on intermediary capital, α, is obtained by equating the aggregate supply and demand for intermediary capital in the economy (assuming that there is no excess supply of intermediary capital at the minimum acceptable rate of return, equal to one). Specifically, α is determined by the following equilibrium condition :

$$K_m = A_m(\alpha)[G(A^*) - G(A^{**}(\alpha))], \textit{ where } A_m(\alpha) = cp_L/\alpha^2 \Delta p$$

$A_m(\alpha)$ represents the minimum amount of intermediary capital that has to be provided for each project requiring monitoring (i.e. in the range $A^* > A_f \geq A^{**}(\alpha)$). The need for intermediary capital arises for the following reason. The intermediary has to be induced to monitor: just like the entrepreneur, he is protected by limited liability, so that monitoring incentives can only be provided by guaranteeing him a sufficiently large share of the project's return when successful. Since there is a strictly positive probability of success even when the intermediary does not monitor, the expected value of the project income that has to be pledged to the intermediary to satisfy his incentive compatibility constraint is strictly greater than the value of his monitoring cost, c. The intermediary therefore "pays" for these expected rents at the beginning, by contributing capital $A_m(\alpha)$ to the project.

However, he may not pay the full value of these expected rents, in the following sense. When intermediary capital in the economy is scarce, the expected rate of return demanded by intermediaries exceeds the expected rate of return demanded by uninformed investors ($\alpha > 1$), implying that intermediaries obtain strictly positive expected rents. Another way of thinking about this is that intermediaries essentially obtain a premium because of their monitoring skills, which are relatively scarce in the economy. As a consequence, entrepreneurs will demand only the minimum amount of intermediary capital, $A_m(\alpha)$, consistent with the provision of monitoring incentives. Any additional requirement for external finance will be met directly from uninformed investors.

3.1. Collusion

The results summarised in Proposition 1 assume that the possibility of collusion can be ruled out a priori. If this is not the case, it can easily be verified that the entrepreneur and the intermediary (in the mixed finance case) will have an incentive to collude during the first period so that the intermediary does not monitor. This follows from the fact that, in the optimal contract when collusion is ruled out exogenously, the intermediary is just indifferent between monitoring and not monitoring (his incentive compatibility constraint is binding), while the entrepreneur can be made strictly better off if the intermediary does not monitor (he can choose the bad project and obtain private benefits of value B). The entrepreneur would therefore like to induce the intermediary not to monitor, if this is not too costly.

How reasonable is it to assume away the possibility of collusion a priori ? One argument in favour of such an assumption might be that the entrepreneur is, by definition, capital-constrained : where would he find the resources necessary to induce the intermediary to collude ? This objection does not seem convincing, since the entrepreneur will typically be in a position that allows him to grant some private benefits to the intermediary, if he wishes; for example, by using corporate resources (including ideas, knowledge and information) to benefit the intermediary, as noted in the introduction. A more persuasive argument might be that the intermediary will not be willing to collude because he will be concerned about the possible damage to his reputation. There are two aspects to this argument. Firstly, there is the possibility that investors might discover ex post that collusion has taken place. However, this is unlikely if sufficient care is taken in choosing the form of the side transfers. A good example here, particularly in the case of high-technology start-ups, would be the sharing of valuable knowledge and information that the entrepreneur possesses and/or acquires in the early stages of the venture. Secondly, an intermediary who systematically colludes with entrepreneurs instead of monitoring the projects will build up, over time, a poorer track record for project success than an intermediary who never shirks on monitoring. This will obviously affect his reputation in the market and hence his ability to stay in business. While concern over such long-term reputational effects will undoubtedly play a role, it seems unlikely that it will provide, on its own, a sufficiently powerful deterrent to collusion at all times. Thus simply ruling out the possibility of collusion by assumption does not seem justified.

The foregoing discussion motivates the more general analysis that follows, which will allow for the possibility of collusion. It is perhaps worth emphasizing that collusion will not take place in equilibrium: the difference with the case examined earlier is that collusion will now be ruled out endogenously, through the optimal design of financial contracts. As discussed above, collusion would require some form of transfer from the entrepreneur to the intermediary, to induce the latter not to monitor. The simplest way to capture the different possible ways in which collusive transfers might occur is through a linear collusion technology: that is, by assuming that a transfer which costs S to the giver benefits the receiver by an amount kS.[11] We assume that $1 \geq k > 0$: the case where $k < 1$ implies the

[11] See Tirole (1992). The no-collusion case examined earlier (Proposition 1) corresponds to assuming that $k = 0$, since in this case a collusive transfer from the entrepreneur would bring

existence of transactions costs of collusion, including, for example, the effect of reputational concerns as discussed above, which would tend to reduce the benefit to the receiver. In principle, the case where $k > 1$ cannot be ruled out: for example, the entrepreneur might possess some private information that is potentially more valuable to the intermediary than to himself. In the remainder of the paper, we focus attention on what we consider to be the most plausible case, $1 \geq k > 0$. With this assumption we obtain the following result:

Proposition 2. Allowing for the possibility of collusion (side transfers at rate k $(1 \geq k > 0)$) raises the minimum amount of entrepreneurial capital required to undertake the good project with mixed finance to:

$A_1^{**}(\alpha) \equiv A^{**}(\alpha) + p_H k(B - b)[1 - (1/\alpha^2)]/\Delta p$, where $A^{**}(\alpha)$ is the critical threshold in the absence of collusion (Proposition 1).

Proposition 2 shows that, even though collusion does not occur in equilibrium, the threat of collusion has an impact on financing constraints. The difference between $A_1^{**}(\alpha)$, the critical threshold level of entrepreneurial capital when collusion is deterred endogenously, and $A^{**}(\alpha)$, the critical threshold level when collusion is assumed away exogenously, can be thought of as measuring the economic cost of the possibility of collusion. It is an opportunity cost, since it represents lost opportunities to undertake good projects. This cost is obviously increasing in k, reflecting the relative ease with which collusion can take place; moreover, it is increasing in α, the equilibrium rate of return on intermediary capital.

The intuition for this result is as follows. For a given collusion technology, there are two ways of preventing collusion, namely increasing the entrepreneur's share of the project's success returns, R_f (thereby reducing his potential gain from collusion, and hence the maximum side transfer he would be willing to make), and increasing the intermediary's share of success returns, R_m (thereby increasing his opportunity cost of collusion, and hence the minimum side transfer he would be willing to accept). At the margin, increasing the share of success returns pledged to the entrepreneur requires an equivalent increase in entrepreneurial capital, whereas increasing the share of success returns pledged to the intermediary requires, at most, only a smaller increase in entrepreneurial capital, since the intermediary can provide additional capital. Thus when the entrepreneur is sufficiently capital-constrained, collusion is prevented by increasing the intermediary's share of success returns: this has a cost when intermediary capital is scarce ($\alpha > 1$), because the intermediary extracts some rents.

It is interesting to compare this result with existing results in the collusion literature, which has not specifically addressed the implications of the possibility

no benefit to the intermediary, who would therefore refuse any offer to collude.

of collusion between entrepreneurs and financial intermediaries such as venture capitalists. The existing literature on collusion in three-tier hierarchies assumes risk aversion (as in Tirole (1986)), the existence of transactions costs of collusion, i.e. $k < 1$, (see Tirole (1992)), or asymmetric information within the coalition (as in Felli (1990)), in order to have a role for the intermediary (supervisor). Without any of these assumptions, the value of the rents that have to be granted to the supervisor to deter collusion is equal to the reduction in the agent's rents which is achieved by employing the supervisor. The principal therefore gains nothing from employing the supervisor. In the present paper, on the other hand, there can be a role for the intermediary even though we are assuming risk neutrality and symmetric information within the coalition, and even if we assume there are no transactions costs of collusion, i.e. $k = 1$.

Specifically, it follows from Propositions 1 and 2 that :

Corollary 1. Assume $k = 1$ (there are no transactions costs of collusion). Financial intermediation (monitoring) is valuable, i.e. $A_1^{**}(\alpha) < A^*$, if and only if the following condition holds :
$p_H(\mathrm{B}-\mathrm{b})/\alpha^2 - \mathrm{c}[p_H - (p_L/\alpha^2)] > 0$

Intermediaries therefore have a role as long as α is not too large, in the sense made precise by corollary 1. The reason is the following. It is still the case that the ex post rents that have to be granted to the intermediary to prevent collusion are equal to the reduction in the entrepreneur's ex post rents which is achieved by inducing the intermediary to monitor. However, the intermediary can "pay" for a greater share of these ex post rents by contributing capital ex ante. Thus bringing the intermediary (monitor) on board will alleviate the agency problem, as long as the opportunity cost of intermediary capital, α, is not too high.

4. Asymmetric information about γ: outside investors do not observe firm prospects at t=1

This section assumes, more realistically, that outside investors do not observe the realisation of γ at t=1, whereas the entrepreneur and the intermediary (the latter, in the case of mixed finance) do. We consider briefly direct finance, then focus on mixed finance.

4.1. Direct finance

The implications of asymmetric information for the possibility of direct finance are straightforward. For the project to be feasible under direct finance, the entrepreneur must be given incentives to take the efficient continuation/liquidation decision at t=1, based on his private information about the state γ. Specifically, his share of liquidation proceeds, L_f, must be such that he prefers liquidation in the bad state ($L_f \geq \gamma_B R_f$) and continuation in the good state ($\gamma_G R_f \geq L_f$). This contrasts with the symmetric information case analysed in section 3, where the entrepreneur's share of liquidation proceeds could be set equal to zero. The entrepreneur's ex ante incentive compatibility constraint requires his share of the project's success returns, R_f, to be sufficiently greater than L_f to induce him to choose the good project. With L_f strictly positive, R_f must also increase. Thus a greater share of the project's income has to be pledged to the entrepreneur, implying that the minimum amount of entrepreneurial capital required to undertake the project is strictly greater than under symmetric information. The following result shows the precise magnitude of this effect.

Proposition 3. Assume that γ is observed by the entrepreneur at t=1 but not by outside investors. Then the entrepreneur can undertake the good project raising all the required external finance from uninformed investors if, and only if, $A_f \geq A_A^* \equiv A^* + \gamma_B B/\Delta\gamma\Delta p$, where A^* is the critical threshold for direct finance under symmetric information (Proposition 1).

As noted above, the entrepreneur's share of liquidation proceeds under asymmetric information is bounded below by the need to provide him with the right incentives to choose the efficient continuation/liquidation decision. Thus, what matters for the firm's ability to raise external finance is not the full value of liquidation proceeds (collateral), as was the case under symmetric information, but rather the maximum liquidation value (collateral) that can be pledged to investors, which will be strictly lower by L_f. This, together with the reduction in pledgeable success returns needed to satisfy the entrepreneur's ex ante ICC, determines the shortfall in external finance which has to be compensated for by an increase in the entrepreneur's own capital contribution. It is worth relating this result to Holmström and Tirole (1997): in their model the fact that entrepreneurs with insufficient own capital cannot raise on financial markets the external finance they would need to undertake good projects is due entirely to the ex ante moral hazard problem associated with project choice. In the present paper, there is an additional effect due to asymmetric information about the firm's prospects at the interim stage, which exacerbates financing constraints and reduces the number of good projects that can be undertaken by accessing directly financial markets.

It is also worth comparing the impact of asymmetric information about γ on the possibility of direct finance, analysed here, with its impact on the possibility of mixed finance in the absence of collusion, analysed in section 4.2.1 below. The critical threshold for direct finance increases (Proposition 3), while the corresponding threshold for mixed finance is unchanged (Proposition 4). The reason is that with only one informed party, the entrepreneur, implementing the optimal continuation/liquidation decision requires increasing his share of project income, which increases the need for entrepreneurial capital, as noted above. By contrast, with two informed parties (the entrepreneur and the intermediary), it is possible to implement the optimal continuation/liquidation decision (relying on subgame perfect implementation) without increasing either party's share of the project's returns in equilibrium, provided the possibility of collusion is ruled out a priori (see below for a fuller discussion).

4.2. Mixed finance

The remainder of section 4 focuses on the case of mixed finance in which external finance is provided partly by uninformed investors and partly by an intermediary, who must be given appropriate incentives to engage in active monitoring. We assume that the entrepreneur and the intermediary observe the realisation of γ at t=1, unlike outside investors. That is, the intermediary always has an informational advantage over uninformed investors ex post. This assumption, standard in the corporate finance literature (see, for example, Rajan (1992), Admati and Pfleiderer (1994), and Schmidt (2003)), is intended to capture the idea that the intermediary has easier access to information about the firm's progress and prospects than outside investors, together with the knowledge and expertise required to interpret the information correctly. For example, venture capitalists typically concentrate their investments in industries or sectors that they know and understand particularly well, having often worked in them (e.g. as entrepreneurs) prior to becoming venture capitalists. This is likely to be especially important for high-technology industries, where considerable technical expertise may be needed to evaluate progress in the early stages of a venture.

4.2.1. Collusion ruled out a priori

Just as in section 3, we begin by considering the benchmark case in which the possibility of collusion is ruled out a priori. The assumed informational structure implies that there are always two informed parties at t=1, the entrepreneur and the intermediary. Ex ante, contracts can therefore be designed to ensure that information about the state γ will be obtained from the informed parties at t=1, and used to implement the efficient continuation/liquidation decision. In the absence of collusion, this can be achieved at no additional cost; that is, the fact that the realisation of γ is only observed by the entrepreneur and the intermediary need not impose any restriction on financing possibilities relative to the mixed finance case analysed in Proposition 1, section 3, where the realisation of γ was assumed to be publicly observable at t=1. The reason is that we can rely on subgame perfect implementation[12] to elicit information about γ from the two informed parties without needing to increase their share of project income in equilibrium. This result is summarised in Proposition 4 below.

Proposition 4. Assume that γ is observed by the entrepreneur and the intermediary at t=1 but not by outside investors, and that collusion is not feasible. Then:

(a) the entrepreneur can undertake the good project under mixed finance if, and only if, $A_f \geq A^{**}(\alpha)$, where $A^{**}(\alpha)$ is the critical threshold under symmetric information (given in Proposition 1);

(b) optimal contracts, which allow the project to be financed whenever $A_f \geq A^{**}(\alpha)$, have the following properties: (i) the equilibrium payoffs of the entrepreneur and the intermediary in the event of liquidation are equal to zero ($L_f = L_m = 0$); and (ii) information about γ is obtained from the intermediary and the entrepreneur at t=1 through a sequential mechanism which requires their agreement for the project to be continued.

Proposition 4(b) shows that, in general, optimal contracts with asymmetric information between the informed "insiders" and the uninformed outside investors with no possibility of collusion are not consistent with the fact that venture capitalists typically hold convertible securities. These represent a claim on at least some of the proceeds in the event of liquidation, which is not consistent with Proposition 4(b)(i). Moreover, the sequential mechanism required to elicit information about γ (which relies on subgame perfect implementation, as discussed above) cannot be interpreted as a convertible security.

The allocation of control rights over the liquidation decision that emerges in these optimal contracts does embody an important feature of observed venture capital contracts, namely the fact that the intermediary has the power to force liquidation. This is consistent with the widespread use of redemption rights, discussed in detail in section 4.2.2 below. On the other hand, the optimal contracts described by Proposition 4 also require the entrepreneur to have the power to force liquidation. The empirical evidence on this is less clear-cut. The reason is that the entrepreneur would typically need to have control of the board to initiate a liquidation; moreover, he may need a voting majority to ensure that the decision is approved (see Smith (2001) and Kaplan and Strömberg (2003)).[13] In their study of 213 venture capital investments, Kaplan and Strömberg (2003)

[12] Essentially this entails giving one party incentives to "call the other's bluff" if the other tries to "cheat", so as to obtain "good" behaviour in equilibrium. For an excellent survey which discusses subgame perfect implementation extensively, see Moore (1992).

[13] Board rights and voting rights can differ in venture capital contracts through the use of explicit agreements on the election of directors (see Kaplan and Strömberg (2003)).

found that entrepreneurs (founders) had the majority of the board seats in 14% of cases, and venture capitalists in 25% of cases. In the remainder of cases neither had control, implying an important role for other board members; however, these were individuals mutually agreed upon by the venture capitalists and the entrepreneurs (founders), suggesting that they could not be counted upon to side systematically with the latter. As for voting rights, the same study revealed that entrepreneurs had a voting majority in at most 24% of all financings, the corresponding figure for venture capitalists being 53%.[14] This suggests that in many cases entrepreneurs do not have the power to force liquidation.

Some intuition for the results described by Proposition 4 can be obtained by comparing them with those presented in section 3. Under symmetric information, ex ante incentives were provided by pledging to the entrepreneur and to the intermediary a sufficiently large share of the project's success returns, and a zero share of any proceeds in the event of liquidation. Ex post efficiency could be guaranteed simply by specifying in the contract the efficient continuation decision contingent on γ, since γ was assumed to be contractable. When γ is only observed by the entrepreneur and the intermediary ex post, as we assume in this section, it is not directly contractable; the information has to be elicited from the two informed parties.

There is some tension between the need to elicit information about γ and the allocation of cashflow rights that was optimal under symmetric information. In particular, when the entrepreneur and the intermediary receive nothing in the event of liquidation (all the proceeds go to uninformed investors), they both always prefer continuation to liquidation (since $\gamma_B R_m > 0$ and $\gamma_B R_f > 0$), which might induce them to claim that the state is good even when this is not the case. This potential difficulty can be addressed using a simple sequential mechanism (see the Appendix for an example), with the property that the entrepreneur and the intermediary share (sequentially) the control rights over the continuation decision; in particular, each party can force liquidation, so that continuation requires agreement. Notice however that this type of mechanism is not collusion-proof: in the bad state, $\gamma = \gamma_B$, the intermediary and the entrepreneur clearly have an incentive to collude to secure higher payoffs. The next section addresses this point, and more generally the issue of collusion.

[14] The calculation of voting rights is complicated by the fact that some of these are contingent on subsequent management performance and stock vesting milestones or contingencies. Kaplan and Strömberg deal with this difficulty by calculating both a minimum and a maximum number of votes for the venture capitalists, depending on future contingencies, and the corresponding votes for the entrepreneurs. In the text I report the figures for the minimum contingency case, which tends to overestimate the control rights of the entrepreneurs. In the maximum contingency case, venture capitalists have a voting majority in 69% of all financings, and entrepreneurs have a voting majority in only 12% of financings.

4.2.2. Collusion

When information about the state γ has to be elicited from the entrepreneur and the intermediary ex post, there is greater scope for collusion than in the symmetric information case analysed in section 3. As before, the entrepreneur and the intermediary may collude ex ante, at t=0, so that the intermediary does not monitor, and the entrepreneur chooses the bad project yielding private benefits B. They may also collude ex post, at t=1, so as to induce continuation even in the bad state, which gives them expected payoffs $\gamma_B R_m$ and $\gamma_B R_f$, respectively. Moreover, while ex-ante collusion would require, as in the symmetric information case considered in section 3, a collusive transfer from the entrepreneur to the intermediary, ex-post collusion could occur even in the absence of any collusive transfers. The reason is that when the entrepreneur and the intermediary do not receive any of the proceeds in the event of liquidation, both parties stand to gain from continuing the project in the bad state. The fact that ex-post collusion could occur in the absence of collusive transfers means that the collusion case considered below will not correspond to the no-collusion case examined above, even when $k = 0$. The following result summarises the implications of these collusion possibilities for financing constraints and investment, and for the form of optimal financial contracts.

Proposition 5. Assume γ is observed by the entrepreneur and the intermediary at t=1, but not by outside investors. Then:

(a) allowing for the possibility of collusion (side transfers at rate k $(1 \geq k > 0)$) raises the minimum amount of entrepreneurial capital required to undertake the good project with mixed finance to:

$A_2^{**}(\alpha) \equiv A_1^{**}(\alpha) + \gamma_B(c + kB)[1 - (1/\alpha^2)]/\Delta p \Delta\gamma$, where $A_1^{**}(\alpha)$ is the corresponding critical threshold with symmetric information, given in Proposition 2;

(b) optimal collusion-proof contracts, which allow the good project to be financed whenever $A_f \geq A_2^{**}(\alpha)$, have the following properties: (i) the intermediary is given control rights over the decision to continue or liquidate the project at t=1; and (ii) the allocation of cashflow rights provides the intermediary with incentives to take the efficient continuation/liquidation decision; this entails giving the intermediary a share of the proceeds in the event of liquidation equal to $L_m = \gamma_B(R_m + kR_f)$.

Financing constraints and investment

Comparing Proposition 5 with Proposition 2 shows the magnitude of the effect on financing constraints due to asymmetric information about γ; that is, the additional effect associated with the possibility of ex post collusion when information about γ has to be elicited from the informed insiders. In principle, there are two ways of deterring the entrepreneur and the intermediary from colluding to continue the project in the bad state: increasing the entrepreneur's share of liquidation proceeds and increasing the intermediary's share of liquidation proceeds. When the entrepreneur is sufficiently capital-constrained, only the second option is available. Raising the intermediary's share of liquidation proceeds also requires an increase in his share of the project's success returns, to satisfy his incentive compatibility constraint. Both increases are costly when intermediary capital is scarce ($\alpha > 1$), which exacerbates the entrepreneur's financing constraint.

Optimal contracts and venture capital

Proposition 5 shows that optimal collusion-proof contracts are consistent with commonly observed characteristics of venture capital contracts. First, the intermediary is given control rights over the continuation decision. In particular, he is given both *the right and the incentives to liquidate the project* in the bad state. The intuition for this is as follows. The possibility of collusion means that we can no longer implement the optimal continuation/liquidation decision while reducing the two informed parties' equilibrium payoffs in the bad state to zero by giving one party the incentive to "call the other's bluff" as the parties would collude to secure higher payoffs. The optimal continuation decision can only be implemented (and collusion deterred) by increasing the entrepreneur's and/or the intermediary's equilibrium payoffs in the event of liquidation. To minimise the need for entrepreneurial capital, we rely on the second option. This implies giving the intermediary the power and the incentives to liquidate the project in the bad state.[15] This is consistent with the use of redemption rights in venture capital contracts: as Gompers (1997) notes, these rights imply that "essentially, the venture capitalists can force the firm to repay the face value of the investment at any time. This mechanism can often be used to force liquidation".[16] Second, the

[15] Notice that, in contrast with the results of Proposition 4, there is no need to give the entrepreneur the right to liquidate. Indeed, whether the entrepreneur has this right or not becomes irrelevant, since he would never have the incentive to exercise it, given his cashflow rights.

[16] Venture capitalists' redemption rights can take one of two forms: mandatory redemption rights and optional investor redemption ("put") rights. Mandatory redemption requires the company to begin repurchasing shares at a specified date, usually subject to waiver by the venture capitalists. Optional investor redemption rights, which are much more common, allow venture capitalists to force the repurchase of their shares at their discretion. They can typically be exercised after a given date. Thus with both types of redemption right, the venture capitalist essentially acquires liquidation rights from a given date onwards. Earlier in the venture capital relationship, the venture capitalist effectively controls the continuation / liquidation decision through the use of staged financing and negative covenants. For a more detailed discussion, see Smith (2001) and Kaplan and Strömberg (2003).

allocation of cashflow rights is also consistent with common practice in venture capital finance, where convertible securities (convertible preferred equity and convertible debt) are the most commonly used financial instruments, as noted earlier. In particular, under plausible assumptions,[17] *the intermediary's payoffs can be interpreted as the payoffs to a convertible security:* let the intermediary hold a debt claim with face value equal to L_m and an option to convert this to an equity share which will have value R_m at t=2 if the project succeeds.

The intermediary clearly has an incentive to continue the project and exercise the conversion option in the good state, since the expected payoff in this case, $\gamma_G R_m$, exceeds the payoff from liquidation, L_m, (because of the intermediary's ex ante incentive constraint), which in turn is greater than the expected payoff from continuing without exercising the conversion option, $\gamma_G L_m$. In the bad state, on the other hand, the intermediary prefers liquidation, since his payoff in this case, L_m, is greater than or equal to the highest possible expected payoff from colluding with the entrepreneur to continue the project (given by $\gamma_B R_m + k\gamma_B R_f = L_m$ if the intermediary exercises the conversion option, and $\gamma_B L_m + k\gamma_B R_f < L_m$ if the intermediary does not exercise the conversion option).

One implication of this interpretation is that *the intermediary's decision to continue and exercise the conversion option can act as a credible signal* to uninformed investors that the firm's prospects are good: this too seems consistent with the empirical evidence on venture capital financing. Continuation finance is often raised through IPOs,[18] and venture capitalists are required to exercise their conversion option at this point. Megginson and Weiss (1991), in their study of 320 venture-backed and 320 nonventure IPOs over the period 1983-87, find that venture capitalists retain a majority of their equity after the IPO, and that the underpricing of venture-backed IPOs is significantly less than the underpricing of nonventure IPOs. They interpret this as evidence that venture capitalists certify to investors the quality of the firms they bring to market. Their argument for this *certification hypothesis* is based on reputational considerations: the idea is that venture capitalists have an incentive to build a reputation for bringing high-quality firms to market, which in turn will reduce the costs of taking firms public in the future. The analysis of this paper suggests that venture capitalists' certi-

[17] We require simply that $L_m/L \geq R_m/R$, i.e. that the intermediary's share of liquidation proceeds be no less than his share of the project's success returns.

[18] The analysis of contracts presented in the Appendix assumes, for ease of exposition, that there is just one contract with uninformed investors, agreed at $t = 0$, and that uninformed investors will then provide the required finance C_1 at $t = 1$ if the decision is taken to continue the project. The analysis can easily be modified to allow for continuation finance to be provided by new uninformed investors at $t = 1$, as would be the case in an IPO. The point is that the entrepreneur's and the intermediary's incentive constraints do not change, so that the results described in the Propositions are not affected.

fication role does not rely only on reputation, but also on the design of financial contracts, which provides the appropriate incentives for certification.

Finally, as noted in the introduction, it is worth emphasizing that while the optimal collusion-proof contract can be implemented with convertible securities or a combination of debt and equity, *it cannot, in general, be implemented with straight debt or straight equity* : this may provide an explanation for the difference between the financial claims typically held by venture capitalists (convertible securities), and those held by business angels for whom the possibility of collusion is not an issue (straight equity).[19]

5. Conclusions

Real-world venture capital contracts are varied, detailed, and complex, as shown by the growing empirical literature. No single stylised theoretical model can hope to explain all of the observed diversity and complexity; nevertheless, a number of papers, including the present one, have made progress in this direction, by highlighting the role of certain key issues and trade-offs in venture capital financing. The model developed here focused on three such interrelated issues: the need to motivate venture capitalists to monitor effectively (thereby alleviating potential entrepreneurial moral hazard problems); the need to provide appropriate incentives to induce efficient continuation and refinancing decisions; and the need to deter collusion between entrepreneurs and venture capitalists at the expense of other investors.

Optimal financial contracts that take this interrelationship into account have a number of features that correspond to observed characteristics of venture capital financing. Nevertheless, the present paper represents only a small step in, I believe, the right direction. In particular, the issue of potential collusion, highlighted in this paper, merits further study. In future work, it would be interesting to extend the analysis by considering whether and in what circumstances it might be desirable to have more than one monitor. This could help to shed light on the widespread practice of syndication. The distinction between venture capitalists' certification and intermediation roles is also a very promising topic for future research.

[19] See Fenn, Liang and Prowse (1998) on business angels and Gompers and Lerner (1999) and Kaplan and Strömberg (2003) on venture capitalists.

6. Appendix

Proofs of all the Propositions follow.

Proof of Proposition 1.

(a) (direct finance) At t=0 the entrepreneur proposes a contract $C^{DS} = \{A_f, A_u, Y(\gamma), L_f, L_u, R_f, R_u\}$ to uninformed investors (who for simplicity will be treated as a single party in what follows). A_f and A_u represent the amounts of capital invested in the project at t=0 by the entrepreneur and the investors, respectively. The decision rule $Y(\gamma)$ determines whether the project will be continued or liquidated at t=1, contingent on the realisation of γ. Specifically, the variable $Y(\gamma)$ takes the value one if the project is continued at t=1, with the required expenditure C_1 being provided by the investors; it takes the value zero if the project is liquidated. The contract further specifies payments to be made at t=1 if the project is liquidated (L_f and L_u), and at t=2 if the project is continued and succeeds (R_f and R_u). The entrepreneur's problem is to maximise his expected payoff subject to the relevant participation, incentive compatibility and feasibility constraints, described below. It is straightforward to verify that any solution to this problem would entail setting $Y(\gamma_G) = 1$ and $Y(\gamma_B) = 0$ (thereby achieving ex post efficiency). Thus without loss of generality we can specify the entrepreneur's problem $(P1)$ as follows:

$$Max \qquad p_H \gamma_G R_f + (1 - p_H) L_f - A_f \tag{6.1}$$

$$s.t. \qquad p_H \gamma_G R_f + (1 - p_H) L_f \geq B + p_L \gamma_G R_f + (1 - p_L) L_f \tag{6.2}$$

$$R_f + R_u = R \tag{6.3}$$

$$L_f + L_u = L \tag{6.4}$$

$$A_f + A_u = C_0 \tag{6.5}$$

$$p_H(\gamma_G R_u - C_1) + (1 - p_H) L_u \geq A_u \tag{6.6}$$

where expression (6.1) represents the entrepreneur's expected payoff, condition (6.2) is the entrepreneur's incentive compatibility constraint (ICC), ensuring that he chooses the good project ex ante; conditions (6.3) to (6.5) are feasibility constraints, and lastly condition (6.6) is the investors' participation constraint.

From the entrepreneur's ICC we obtain the following condition for R_f:

$$R_f \geq B/\Delta p \gamma_G + L_f/\gamma_G \tag{6.7}$$

Using this, together with the condition

$$L_f \geq 0 \tag{6.8}$$

due to the entrepreneur's limited liability, the maximum returns that can be pledged to investors are derived from the feasibility constraints (6.4) and (6.5):

$$L_u^{\max} = L \tag{6.9}$$

$$R_u^{\max} = R - B/\Delta p \gamma_G \tag{6.10}$$

Substituting these upper bounds into expression (6.6) gives the maximum amount of capital that can be raised from uninformed investors:

$$A_u^{\max} = p_H(\gamma_G R - B/\Delta p - C_1) + (1 - p_H)L \tag{6.11}$$

The project can only be financed if the entrepreneur has sufficient capital to make up the difference between the required initial expenditure, C_0, and the maximum amount of capital that can be raised from investors, $A_u^{\max}$. This gives the following condition:

$$A_f \geq A^* = C_0 - p_H(\gamma_G R - B/\Delta p - C_1) - (1 - p_H)L \tag{6.12}$$

When the above condition is satisfied, it can be easily checked that the following is a solution to $P1$: let $A_f = A^*$, $A_u = C_0 - A^*$, $Y(\gamma_G) = 1$, $Y(\gamma_B) = 0$, $L_f = 0$, $L_u = L$, $R_f = B/\Delta p \gamma_G$, $R_u = R - B/\Delta p \gamma_G$.

(b) (mixed finance) I focus here on the case where direct finance is not feasible ($A_f < A^*$), so that the entrepreneur has to turn to an intermediary, who needs to be given incentives to monitor. At t=0 the entrepreneur proposes a contract $C^{MS} = \{A_f, A_u, A_m, Y(\gamma), L_f, L_u, L_m, R_f, R_u, R_m\}$ to the intermediary and the uninformed investors. The form of the contract is similar to the one for the direct finance case described above, C^{DS}; the difference is that it also specifies the intermediary's capital investment at t=0 (A_m), his payoff at t=1 if the project is liquidated (L_m), and his payoff at t=2 if the project succeeds (R_m). As was the case for direct finance, it is straightforward to verify that any solution to the entrepreneur's problem would entail setting $Y(\gamma_G) = 1$ and $Y(\gamma_B) = 0$ (thereby achieving ex post efficiency). Thus without loss of generality we can specify the entrepreneur's problem ($P2$) as follows:

$$Max \qquad p_H\gamma_G R_f + (1-p_H)L_f - A_f \tag{6.13}$$

$$s.t. \qquad p_H\gamma_G R_f + (1-p_H)L_f \geq b + p_L\gamma_G R_f + (1-p_L)L_f \tag{6.14}$$

$$R_f + R_u + R_m = R \tag{6.15}$$

$$L_f + L_u + L_m = L \tag{6.16}$$

$$A_f + A_u + A_m = C_0 \tag{6.17}$$

$$p_H(\gamma_G R_u - C_1) + (1-p_H)L_u \geq A_u \tag{6.18}$$

$$p_H\gamma_G R_m + (1-p_H)L_m \geq c + p_L\gamma_G R_m + (1-p_L)L_m \tag{6.19}$$

$$p_H\gamma_G R_m + (1-p_H)L_m - c \geq \alpha^2 A_m \tag{6.20}$$

Expression (6.13) represents the entrepreneur's expected payoff, while his incentive compatibility constraint is given by (6.14). Expressions (6.15) to (6.17) are feasibility constraints, and (6.18) is the investors' participation constraint. The intermediary's incentive compatibility and participation constraints are given by (6.19) and (6.20), respectively.

The method of proof is the same as for *(a)* above: firstly, obtain lower bounds for R_f, R_m, L_f and L_m, using the entrepreneur's and the intermediary's ICCs, together with limited liability. Secondly, using these lower bounds together with the participation constraints, derive the minimum amount of entrepreneurial capital required for the project to be undertaken. Notice that, since $\alpha^2 \geq 1$, we can focus without loss of generality on the case where the intermediary's capital investment, A_m, is just equal to the minimum amount necessary to satisfy his participation and incentive compatibility constraints; any additional external finance is raised directly from investors.

From the entrepreneur's ICC, together with limited liability, we have:

$$R_f \geq b/\Delta p\gamma_G + L_f/\gamma_G \tag{6.21}$$

$$L_f \geq 0 \tag{6.22}$$

and from the intermediary's ICC, together with limited liability, we have:

$$R_m \geq c/\Delta p\gamma_G + L_m/\gamma_G \tag{6.23}$$

$$L_m \geq 0 \tag{6.24}$$

Using the lower bounds implied by (6.23) and (6.24), and the intermediary's participation constraint, we obtain:

$$A_m = cp_L/\alpha^2\Delta p \tag{6.25}$$

Using conditions (6.21) to (6.24), together with the feasibility constraints (6.15) and (6.16), gives the following upper bounds for R_u and L_u :

$$R_u^{\max} = R - (b+c)/\Delta p\gamma_G \tag{6.26}$$

$$L_u^{\max} = L \tag{6.27}$$

Hence the maximum amount of capital that can be raised from investors is obtained from their participation constraint:

$$A_u^{\max} = L + p_H[\gamma_G R - C_1 - L - (b+c)/\Delta p] \tag{6.28}$$

Expressions (6.17), (6.25) and (6.28) together imply that the project can only be financed if the entrepreneur's capital satisfies the following condition:

$$A_f \geq A^{**}(\alpha) = C_0 - L - p_H[\gamma_G R - C_1 - L - (b+c)/\Delta p] - cp_L/\alpha^2\Delta p \tag{6.29}$$

When the above condition is satisfied, it can be easily checked that the following is a solution to $P2$: let $A_f = A^{**}$, $A_m = cp_L/\alpha^2\Delta p$, $A_u = C_0 - A_f - A_m$, $Y(\gamma_G) = 1$, $Y(\gamma_B) = 0$, $L_f = 0$, $L_m = 0$, $L_u = L$, $R_f = b/\Delta p\gamma_G$, $R_m = c/\Delta p\gamma_G$, $R_u = R - R_f - R_m$. *Q.E.D.*

Proof of Proposition 2.

As in the mixed finance case without collusion (Proposition 1(b)), the entrepreneur at t=0 proposes a contract $C^{MS} = \{A_f, A_u, A_m, Y(\gamma), L_f, L_u, L_m, R_f, R_u, R_m\}$ to the intermediary and the uninformed investors. The difference is that the contract needs to be collusion-proof. Hence the entrepreneur's problem, $P3$, is the same as in the no-collusion case ($P2$), given by expressions (6.13) to (6.20), except for the intermediary's ICC, (6.19), which is modified as follows:

$$p_H\gamma_G R_m + (1-p_H)L_m \geq c + p_L\gamma_G R_m + (1-p_L)L_m + kS \tag{6.30}$$

where S is the maximum side transfer that the entrepreneur would be willing to make to the intermediary to induce him not to monitor, and is equal to:

$$S = B - \Delta p(\gamma_G R_f - L_f) \tag{6.31}$$

The lower bounds for R_f and L_f are unchanged relative to $P2$, and can be obtained from expressions (6.21) and (6.22), assuming they hold with equality. Substituting these in (6.31), and then using (6.30) and (6.31), we obtain the following condition for R_m :

$$R_m \geq c/\Delta p\gamma_G + L_m/\gamma_G + k(B - b)/\Delta p\gamma_G \tag{6.32}$$

while limited liability implies, as before, that $L_m \geq 0$. The amount of capital provided by the intermediary can therefore be derived from his participation constraint:

$$A_m = cp_L/\alpha^2\Delta p + p_H k(B - b)/\alpha^2\Delta p \tag{6.33}$$

The maximum amount of capital that can be raised from investors is given by:

$$A_u^{\max} = L + p_H[\gamma_G R - C_1 - L - (b + c + k(B - b))/\Delta p] \tag{6.34}$$

Further manipulation shows that the project can be financed if and only if:

$$A_f \geq A_1^{**}(\alpha) = A^{**}(\alpha) + (1 - 1/\alpha^2)p_H k(B - b)/\Delta p] \tag{6.35}$$

Q.E.D.

Proof of Proposition 3.

At t=0 the entrepreneur proposes a contract $C^{DA} = \{A_f,\ A_u,\ Y(\gamma),\ L_f,\ L_u,\ R_f,\ R_u\}$ to uninformed investors. The contract takes the same general form as the direct finance contract under symmetric information, C^{DS} (described in the proof to Proposition 1(a)), except that now γ is no longer verifiable at t=1, so that the decision rule $Y(\gamma)$ must be incentive-compatible. Specifically, since only the entrepreneur observes γ, the continuation/liquidation decision must be taken by the entrepreneur, who must be given appropriate incentives. It is straightforward to verify that even in this case any solution to the entrepreneur's problem would entail setting $Y(\gamma_G) = 1$ and $Y(\gamma_B) = 0$

The entrepreneur's problem under symmetric information ($P1$), described by expressions (6.1) to (6.6), is therefore modified through the addition of the following ex post incentive compatibility constraints:

$$\gamma_G R_f \geq L_f \tag{6.36}$$

$$L_f \geq \gamma_B R_f \tag{6.37}$$

ensuring that the entrepreneur prefers continuation in the good state and liquidation in the bad state. Using these ex post ICCs together with the ex ante ICC (7.2) the lower bounds for R_f and L_f can be obtained:

$$R_f \geq B/\Delta p \Delta \gamma \tag{6.38}$$

$$L_f \geq \gamma_B B/\Delta p \Delta \gamma \tag{6.39}$$

Using these together with the feasibility constraints and the investors' participation constraint ((6.3), (6.4) and (6.6)) the maximum amount of capital investment by the investors can be derived as:

$$A_u^{\max} = L + p_H[\gamma_G R - C_1 - L] - [p_H \gamma_G + (1 - p_H)\gamma_B] B/\Delta \gamma \Delta p \tag{6.40}$$

The project can therefore be financed if and only if:

$$A_f \geq A_A^* = A^* + \gamma_B B/\Delta \gamma \Delta p \tag{6.41}$$

Q.E.D.

Proof of Proposition 4.

Denote by $C1 = \{A_f,\ A_u,\ A_m,\ \Psi_1,\ L_f,\ L_u,\ L_m,\ R_f,\ R_u,\ R_m\}$ the contract proposed by the entrepreneur to the intermediary and the uninformed investors at t=0. The contract takes the same general form as the mixed finance contract under symmetric information, C^{MS} (described in the proof to Proposition 1(b)), except that it cannot specify a decision rule for the continuation decision, $Y(\gamma)$, contingent on γ. Instead, it specifies a mechanism Ψ_1, to be played at t=1, which is designed to implement the same outcome as the optimal contingent decision rule $Y(\gamma)$ in contract C^{MS}: that is, it is designed to ensure that the project is continued when $\gamma = \gamma_G$, with payoffs R_f, R_u, and R_m in the event of success and zero otherwise, and liquidated when $\gamma = \gamma_B$, with payoffs L_f, L_u, and L_m.

Consider the following mechanism Ψ_1:

- *Stage 1*: the intermediary chooses between continuation and liquidation. If he chooses liquidation, the project is liquidated; payoffs are L_f, L_u, and L_m. If the intermediary chooses continuation, go on to stage 2.

- *Stage 2*: the entrepreneur decides whether to agree with the intermediary or disagree. If he agrees, the project is continued, investors provide the required finance C_1, and payoffs are R_f, R_u, and R_m if the project succeeds; zero otherwise. If the entrepreneur disagrees, the project is liquidated; the entrepreneur receives $\gamma_B R_f + \epsilon$, the investors any remaining liquidation proceeds, and the intermediary zero.

For Ψ_1 to work, it has to satisfy the following conditions[20]:

$$\gamma_G R_f \geq \gamma_B R_f + \epsilon \tag{6.42}$$

$$\gamma_B R_f + \epsilon \geq \gamma_B R_f \tag{6.43}$$

$$L_m \geq 0 \tag{6.44}$$

$$\gamma_G R_m \geq L_m \tag{6.45}$$

Conditions (6.42) and (6.43) ensure that in stage 2 the entrepreneur agrees if $\gamma = \gamma_G$, and disagrees if $\gamma = \gamma_B$. Conditions (6.44) and (6.45) ensure that in stage 1 the intermediary prefers to liquidate if $\gamma = \gamma_B$ and to continue if $\gamma = \gamma_G$. Clearly ϵ can always be chosen to satisfy (6.42) and (6.43). Comparing the above conditions with those for problem $P2$, given in the proof for Proposition 1(b), shows that they impose no additional restriction: it is therefore possible to implement the lower bounds for R_f, R_m, L_f, and L_m implied by (6.21) to (6.24). Thus the minimum level of entrepreneurial capital required for the project to be feasible satisfies the condition:

$$A_f \geq A^{**}(\alpha) \tag{6.46}$$

as was the case under symmetric information.

Notice that the particular mechanism Ψ_1 described above is just one of the possible sequential mechanisms that can be used to implement the lower bounds for R_f, R_m, L_f, and L_m implied by (6.21) to (6.24). The key characteristic of any such mechanism is that it exploits subgame perfection to elicit information

[20] To be consistent with the approach followed in the rest of the paper, which adopts the standard approach in principal-agent problems, I require only weak optimality - hence the weak inequalities. If strong optimality (i.e. unique implementation) is required (as is generally the case in the literature on subgame perfect implementation, e.g. Moore and Repullo (1988), Moore (1992)), these should be replaced by strict inequalities.

from the two informed parties (essentially by giving one party incentives to "call the other's bluff" if the other tries to "cheat"), implying that the project will be continued if, and only if, the two parties agree. *Q.E.D.*

Proof of Proposition 5.

As in the no-collusion case examined in Proposition 4, the entrepreneur at t=0 proposes a contract $C2 = \{A_f, A_u, A_m, \Psi_2, L_f, L_u, L_m, R_f, R_u, R_m\}$ to the intermediary and the uninformed investors. The difference is that the contract needs to be collusion-proof. Once we allow for the possibility of collusion, the entrepreneur and the intermediary can always agree to make the same announcements when $\gamma = \gamma_B$ as when $\gamma = \gamma_G$, giving the outcome {continuation, success payoffs R_f, R_m} with expected payoffs equal to $\gamma_B R_f$, $\gamma_B R_m$. Thus it is no longer possible to implement the equilibrium payoffs that were optimal when collusion was ruled out a priori. To implement the optimal continuation/liquidation decision while minimising the returns pledged to the entrepreneur (hence minimising the need for entrepreneurial capital), we must have:

$$L_f = 0 \tag{6.47}$$

and set L_m so that the intermediary prefers liquidation to continuation when $\gamma = \gamma_B$ (in particular, so that he cannot be induced to collude with the entrepreneur to choose continuation):

$$L_m \geq \gamma_B R_m + k\gamma_B R_f \tag{6.48}$$

The intermediary's ex ante ICC (see below) requires that the intermediary prefer continuation when $\gamma = \gamma_G$ (otherwise he has no incentives to monitor). Without loss of generality we can therefore specify the mechanism Ψ_2 as follows:

- at t=1 the intermediary decides whether to continue the project or liquidate it. If the project is liquidated, the entrepreneur receives $L_f = 0$, the intermediary $L_m = \gamma_B R_m + k\gamma_B R_f$, and the investors any remaining liquidation proceeds. If the project is continued, investors provide the required finance C_1, and payoffs are given by R_f, R_u, R_m (0) in the event of success (failure).

The contract ($C2$) must also prevent collusion ex ante, to ensure that the intermediary monitors (as in Proposition 2). The intermediary's ex ante ICC is therefore given by (6.30). The lower bounds for R_f and L_f are unchanged, and are given by (6.21) and (6.22), implying that the lower bound for R_m is given by (6.32); substituting for L_m using (6.48) gives the following condition:

$$R_m \geq c/\Delta p\Delta\gamma + \gamma_B kb/\gamma_G \Delta p\Delta\gamma + k(B-b)/\Delta p\Delta\gamma \tag{6.49}$$

Let $R_m^{\min} = c/\Delta p\Delta\gamma + \gamma_B kb/\gamma_G\Delta p\Delta\gamma + k(B-b)/\Delta p\Delta\gamma$. Then (using also (6.48)) the amount of capital provided by the intermediary is equal to:

$$A_m = [p_H\gamma_G + (1-p_H)\gamma_B]R_m^{\min}/\alpha^2 + (1-p_H)k\gamma_B b/\alpha^2\Delta p\gamma_G - c/\alpha^2 \quad (6.50)$$

Further manipulation shows that the project can be financed if and only if:

$$A_f \geq A_2^{**}(\alpha) = A_1^{**}(\alpha) + \gamma_B(c+kB)][1-(1/\alpha^2)]/\Delta p\Delta\gamma \quad (6.51)$$

Q.E.D.

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