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The Design of Syndicates in Venture Capital

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The design of syndicates in venture capital. *

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Abstract

The formation of venture capital syndicates is a process characterized by two-sided asymmetric information, as the profitability signals acquired by different VCs are non-verifiable and manipulable. We analyze how appropriate design of the syndicating VCs' cash-flow rights can induce them to reveal their signals to each other truthfully, and how the incentive costs of syndication vary with the VCs' expertise in evaluating entrepreneurial projects. We then address the question of how lead venture capitalists should choose their syndication partners. Our findings suggest that lead VCs should not syndicate with partners much more experienced than themselves even if such partners are available: more experienced venture capitalists should select more experienced partners. This is consistent with the empirical evidence.

Keywords: Venture Capital, Syndication Deals, Asymmetric Information.

JEL Classification: G24, G30, D82

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1 Introduction

A common feature of venture capital finance is that investments are often syndicated, that is, two or more venture capitalists participate in the financing of a project. Typically, the first (lead) venture capitalist to come into contact with the start-up performs his own evaluation of the project but later seeks another venture capitalist's opinion. This may happen at the first investment round (seed stage), but is especially frequent when follow-on investments are considered. Indeed, the decision to refinance the company at a given valuation may be made explicitly conditional on the identification of a new venture capitalist willing to lead the financing round. It is understood that the late-joining venture capitalists provide additional screening of the project ("due diligence"), participate in the financing round and are then entitled to part of the control and cash-flow rights over the venture. In many syndication deals, early and late joining VCs hold different financial claims: while the lead VC typically holds primarily convertible preferred stock, late VCs often hold participating convertible preferred stock and have senior rights in case of liquidation.

There are several theories explaining why venture capitalists would wish to share the returns from a profitable project by syndicating. According to the selection hypothesis (Lerner, 1994), syndication is a way for the lead VC to obtain a second assessment of the project and thus improve the selection process for risky ventures. The value-added hypothesis (Amit, Antweiler and Brander, 2002) instead stresses venture capitalists' ability to create value by providing advice and bringing business connections once the project has been funded. In this respect, different VCs may bring different and complementary skills to the project, thus making syndication desirable. Finally, VCs may pursue syndication simply to share risk, or to overcome capital constraints when the financing needs of the venture are large. Probably, more than one rationale lies behind most syndication decisions.[1]

In this paper we focus on the first rationale for syndication, namely the need for a second expert evaluation to improve the selection process of entrepreneurial ideas. We argue that various incentive issues arise in a VC syndicate due to the non-verifiability and manipulability of private signals. Consider first the second VC's information gathering process. The lead VC ($VC1$) cannot observe whether his potential syndication partner ($VC2$) expends costly effort to acquire information about the firm or not, and hence must provide $VC2$ with an incentive to gather her signal. Furthermore, since the signal is soft information (i) $VC2$

[1] Which rationale is most important in practice is largely an empirical question. Amit, Antweiler and Brander (2002) provide evidence that the first three motives matter, while capital constraints are unlikely to explain the wide extent of syndication observed in the VC industry. Lockett and Wright (2001) find that the motives for syndicating a deal vary according to the investment stage of the deal.

may not report the signal truthfully to $VC1$ if she has observed one; (ii) $VC2$ may report a signal even if she has not observed anything. A further incentive issue arises from the fact that the lead venture capitalist's signal is also manipulable. $VC1$ may then be tempted to provide a false (overly optimistic) assessment of the project and propose a syndication contract to $VC2$ even though she has received bad news about the project's profitability: it is not uncommon to hear a venture capitalist describe one of his peers as having "fallen in love with a deal" and having an inflated notion of the company's worth. Hence, $VC2$ will fear that she is buying an over-priced claim, unless the syndication contract ensures that $VC1$'s report is truthful. In this paper we study how an appropriate design of cash-flow rights can induce the syndicating VCs to truthfully reveal their signals to each other via their decision as to whether co-finance the project.

We then investigate how the incentive costs of syndication vary with the VCs' levels of expertise, in order to address a question which is central to VC syndication, namely *how lead VCs choose their syndication partners*. We first ask whether lead VCs should always syndicate their investments with the most experienced VC available. In the benchmark case where $VC1$'s signal is public, we find that syndicating with a more experienced venture capitalist is always more valuable to the lead VC, in that a second signal of better precision significantly improves the investment selection process and can be obtained at no extra incentive cost from $VC2$. This is in line with previous results on the formation of venture capital syndicates (see Casamatta and Haritchabalet, 2003). However, we show that when the lead VC also holds a manipulable signal, the incentive costs of syndication (namely, $VC2$'s rent) increase as $VC2$'s expertise increases relative to $VC1$'s expertise. Indeed, we provide examples where the gains from syndication are maximized if the syndication partner is "not too experienced". Finally, we address the related question of who syndicates with whom. We solve our model numerically and in all our examples we find that the optimal level of $VC2$'s expertise is increasing in $VC1$'s expertise. This result, that more experienced VCs tend to syndicate with each other, is in line with existing empirical evidence (Lerner, 1994).

These theoretical arguments also correspond well to the rationales for and the practice of syndication in clinical studies of the venture capital industry. For instance, during the financing of Endeca Technologies (Lerner, Hardymon, and Leamon, 2002), the venture capital funds who had completed the first two financing rounds prior to the 2000 NASDAQ decline strongly encouraged the company to seek a new lead venture capitalist when it sought to raise a "C" (third) financing round in 2001. In large part, this desire appears to have been driven by uncertainty about what the appropriate value for a young Internet commerce company was in the post-crash environment. The new investors—who were concerned that the existing venture investors may have been relying on them to keep afloat a firm that had only modest future prospects—insisted on having participating preferred stock, whereas the earlier rounds had been structured with convertible preferred securities.

Our paper contributes to the theoretical literature on venture capital finance. Many papers in this literature have analyzed the design of venture capital deals in the presence of multiple incentive problems. Yet, the focus so far has been mostly on the incentive issues arising in the relationship between the venture capitalist and the entrepreneur.[2] In this context, Fluck et al. (2006) show how a commitment to syndication can provide an initial venture capitalist with a commitment not to expropriate the entrepreneur's effort, alleviating the hold-up problem that occurs in the absence of syndication, and, for some parameter values, enhancing project value. Dorobantu (2006) considers the incentive problem between the venture capitalist and his potential investors, showing that underpricing in syndication can signal the venture capitalist's ability to investors in future funds.

Our paper instead focuses on the incentive problems arising *within a venture capital syndicate*. The literature on this topic is still relatively small. Casamatta and Haritchabalet (2003) provide an analysis of syndication deals in a model where VCs perform independent evaluations of an investment project, yet their signals are public. In their model, the cost of syndication stems from the possibility that the second expert might "steal" the investment opportunity after evaluating it, which obliges the first VC to write a co-ownership contract with the partner.[3] Hence, their focus is on whether to syndicate or not, a decision which must trade off the benefit from relying on a second VC's assessment with the cost of sharing rents with the syndication partner. They find that syndication is less worthwhile for experienced venture capitalists - so that experienced venture capitalists, if they syndicate at all, will do so only with experienced partners. More recently, Tykvova (2007) shows in a complete information setting that venture capitalists may choose to syndicate with less experienced partners if the latter accumulate experience through syndication and are willing to pay for this. In our model, we assume that parameters are such that the first VC finds it beneficial

[2]See for instance Casamatta (2003), Schmidt (2003), Repullo and Suarez (2004), Dessi (2005), and Cestone (2005).

[3]Thus their model is more appropriate for the study of the syndication of first round investments where the second VC could propose a contract to the entrepreneur that completely cuts out the first venture capitalist. In our model, the first VC has already invested in the project, and so it is impossible for the second VC to contract separately with the entrepreneur. Hence we view our model as being more suited to the modelling of second and later stage syndications: this is particularly true because we assume that the first VC already has a signal about the project's quality from his initial funding of the project.

to syndicate (in a symmetric information world), and focus on how the private, non-verifiable and manipulable nature of VCs' information affects the design of syndication contracts, as well as the choice of syndication partner. This leads us to the unexpected result, mentioned above, that it is not always desirable to choose the most experienced syndication partner.

The paper most closely related to our own is Admati and Pfleiderer (1994), who consider a setting where an entrepreneur, and potentially an incumbent venture capitalist, have private information concerning the profitability of continuing a project. They show that the incumbent venture capitalist can credibly signal the value of continuation by retaining a fixed fraction of the project as it progresses through staged financings - because in this way, his incentive to over-price shares as a seller is exactly offset by his incentive to underprice shares as a buyer. Our model improves on theirs in two important ways. First, in their model, the new venture capitalists are needed only to provide capital (and not expertise or information). In reality, syndication still occurs when the initial venture capitalist would have sufficient capital to fund the firm for another round because, as mentioned above, an important rationale for syndication is the provision of information. The incumbent VC seeks new VCs to provide a credible valuation of the project, implying that those those new VCs will join in the financing of the project.[4] Second, the Admati-Pfleiderer model concludes that the share of the firm that the original venture investors hold will remain constant, across the rounds, while in practice we observe considerable variation in these stakes. We show that a fixed fraction setting is not necessary to induce the initial venture capitalist to reveal his information about likely project returns truthfully, but that a range of other contracts can achieve this aim when the joining venture capitalist is not too experienced. On the other hand, when the joining VC is very experienced compared to the initial VC, we show that it will be necessary for the latter to underprice the firm to induce the new VC to join, even if the market for syndication is perfectly competitive.

Our paper also contributes to the literature on providing incentives for experts. Gromb and Martimort (2007) analyze the incentive issues arising when a principal hires experts to gather two independent signals (of exogenous quality) about a project. They show that a principal can reduce the incentive costs of delegated expertise by relying on two experts rather than one and using one expert's report to cross-check the other's. By contrast, in our model one expert (the lead VC), who already has a private signal about a project, "hires"

[4]While it may be the case that in the financing round immediately before the firm goes public, the venture syndicate opens the doors to institutional investors who are less in a position to undertake a careful assessment of the company, in the initial follow-on financings (the B, C and D rounds), the nature of the new venture investors and the validation that their investments provide is of critical importance to the original investors.

a second expert (the late VC) to perform a second assessment of the project. The second expert must be motivated to gather her signal, and both experts must have incentives to report their signals truthfully to each other. Hence, $VC1$ is an informed principal, whose contract offer conveys information to the agent, and at the same time motivates the agent to gather and report information. In this setting, we show that the incentive costs borne by the informed principal are significantly affected by the quality of the agent's signal, and we make predictions on how principals should select their agents according to their level of experience (quality of their signal).[5]

2 The basic model

In the following, we will set up a highly stylized model of the venture capital syndication process, which will allow us to focus on the particular issue in which we are interested. We consider that an incumbent (or lead) venture capitalist, whom we shall call $VC1$, has already made an initial investment in a firm and is considering whether to inject a further amount of cash I to continue the firm or else to close the firm. For simplicity, we assume that the incumbent VC initially owns all the cash flow rights to the project, but may sell some of these claims to a second venture capitalist in a syndication deal if they go ahead with a further round of financing.[6] The amount of financing required to continue the project I is commonly known to (potential) financiers, but the project's final returns R are uncertain and may turn out to be high H, or low L, with $0 < L < I < H$. The *a priori* probability of success is $q \equiv \Pr(H)$, while $1 - q = \Pr(L)$. We assume that the risk that the project fails and yields only L is sufficiently high that providing funds I to the project in the absence of

[5] Also in contrast to Gromb and Martimort, where transfers paid to agents may come out of the principal's pocket, in our model payments to experts come out of the project's returns. This imposes an extra "budget-balance" constraint on our problem; though our second agent (venture capitalist) can supply funds to the project and thus does not necessarily benefit from limited liability ex ante. We believe that this is a more appropriate framework within which to analyse our particular problem of interest: the choice of syndicate partner and the structure of VCs' claims in a syndicate.

[6] Clearly, this is not a literal description of the situation in most venture capital deals, for at least two reasons. First, usually the entrepreneur (founder, management team, angel investors) will hold some (common) equity. A simple way to incorporate this consideration into our model would be to interpret $VC1$ as being a composite of all of the incumbent claimants. This interpretation is not completely perfect as it is likely that incumbent claimants differ in their ability to inject cash into the firm in later rounds. But if (for example) the entrepreneur is wealth-constrained and cannot inject more cash, one can just consider that the returns H and L in the model are net of any payments that must be made to the entrepreneur in the two states. Second, rather than early venture capitalists *selling* existing equity to venture capitalists which join later, typically the firm will *issue* more equity. Evidently, if it were not for the existence of incumbent claimants other than early-stage venture capitalists just noted who will also be diluted by the issue of new claims, these two operations would be mathematically equivalent.

any expert opinion about the firm's prospects is unprofitable:[7]

$$qH + (1-q)L - I < 0.$$

Information structure and VC expertise

We assume that through his initial funding of the project, $VC1$ receives some *private* information about the likely returns of the project. The quality of such information depends on $VC1$'s expertise. In particular, $VC1$ has a binary signal s_1 about returns, $s_1 \in \{B, G\}$, of precision $\theta_1 \in \left(\frac{1}{2}; 1\right]$, defined as $\theta_1 = \Pr(G/H) = \Pr(B/L)$. The probability of receiving a high signal $s_1 = G$ when the project is profitable increases with $VC1$'s expertise θ_1. Given his signal, $VC1$ updates his belief about the project's probability of success. We denote by $q(G)$ the probability of success conditional on $VC1$ receiving a good signal:

$$q(G) = \frac{q\theta_1}{q\theta_1 + (1-q)(1-\theta_1)}.$$

We also define $p(G)$ as the unconditional probability that signal $s_1 = G$ is observed by $VC1$. For instance, $p(G) = q\theta_1 + (1-q)(1-\theta_1)$.

After receiving the signal s_1, $VC1$ may (i) reject the project, (ii) finance the project alone, or (iii) ask for a second expert's opinion. We assume that even after conditioning upon $s_1 = G$, the project's NPV (defined as $V(G)$) is negative:

$$V(G) \equiv q\theta_1(H-I) + (1-q)(1-\theta_1)(L-I) < 0, \qquad (A1)$$

which implies that $VC1$ never undertakes the project alone. This assumption will simplify our analysis.[8] One can view the assumption as restricting attention to projects which are not too profitable in expectation (these highly profitable projects $VC1$ might prefer to undertake alone). Rearranging the constraint, we can see that, for a given a priori profitability, it imposes an upper bound on $VC1$'s expertise, since otherwise $VC1$ could always be sufficiently confident that projects about which he had received a good signal would succeed:

[7] We make this assumption in order that it is always worthwhile to collect information if the project is to be continued. If this assumption did not hold, there would still be a benefit to collecting information if the value of avoiding projects which are likely to be unprofitable was large enough relative to the cost of collecting information, which will hold provided the project is sufficiently risky. We believe that the insights that would arise from this case would be similar, but the constraints would be more complicated.

[8] Similar incentive issues would arise if assumption $(A1)$ were reversed, but this simplification allows us to abstract from the decision of *whether* to syndicate, focusing rather on *how* to design the syndicate. For an analysis of the decision of whether to syndicate in the case of complete information, see Casamatta and Haritchabalet (2003).

$$\theta_1 < \frac{(1-q)(I-L)}{(1-q)(I-L)+q(H-I)} \equiv \overline{\theta}_1,$$

where clearly $\overline{\theta}_1 < 1$. Clearly, if for a given profitability of project, $VC1$'s signal is sufficiently precise, $VC1$ would be happy to continue the project without acquiring any further information, as in Casamatta and Haritchabalet (2003); for simplicity, we rule out this case and focus instead on the case when $VC1$ always wants to form a syndicate.

After receiving a good signal, $VC1$ will then ask a second venture capitalist, $VC2$, to evaluate the project, and to participate in the financing if the project is continued. The investment cost and the final returns are shared according to a syndication contract that $VC1$ offers to $VC2$. The second VC is an outsider to the project, hence he has to make an (unobservable) information gathering effort at private cost Ψ, to collect a signal $s_2 \in \{B, G\}$ with precision $\theta_2 \in \left(\frac{1}{2}; 1\right]$, defined as $\theta_2 = \Pr(G/H) = \Pr(B/L)$. The two signals s_1 and s_2 are independent conditional on the project outcome, and are *soft information*, i.e. they cannot be observed by other parties. $VC1$ and $VC2$'s levels of expertise in evaluating projects, θ_1 and θ_2, can in principle be different.

If $VC1$ is able to obtain $VC2$'s opinion, he then updates his prior about the likelihood of success, which becomes $q(s_1, s_2)$. For instance, if $VC1$ learns that both signals are good:

$$q(G, G) = \frac{q\theta_1\theta_2}{q\theta_1\theta_2 + (1-q)(1-\theta_1)(1-\theta_2)}.$$

We also define $p(s_1, s_2)$ as the unconditional probability that signals s_1 and s_2 are observed, while $p(s_2/s_1)$ is the probability that s_2 is observed given s_1.

Timing and syndication contract

The timing of events is as follows. The first VC observes the private signal s_1, and then offers a contract to $VC2$ as a way to gather a second opinion about the project. $VC2$ may accept the contract offer or not. If she does, she may collect the signal s_2 at cost Ψ. She then makes a report $\widehat{s}_2 \in \{B, G\}$ to $VC1$. Upon this signal report, the project may be funded (which in equilibrium will occur if and only if $\widehat{s}_2 = G$), or not. The initial contract offer specifies the amount of funds $F \in [0, I]$ that $VC2$ must provide in case the project is funded, and $VC2$'s return in case the project succeeds (fails), R_2^H (R_2^L). $VC1$ then provides funds $I - F$ and expects a payment $H - R_2^H > 0$ in case of success ($L - R_2^L > 0$ in case of failure). That is, we impose budget balance on the project overall. We also impose that VCs' claims must be non-decreasing, that is, $\Delta R_2 \equiv R_2^H - R_2^L > 0$ and $H - L - \Delta R_2 > \dot{0}$. This assumption can be justified either by the assumption that either VC can secretly add cash to the project to increase returns, or else that VCs can "sabotage" the project, decreasing returns (see Innes 1990).

We assume that $VC1$ controls the project and thus has all the bargaining power vis-à-vis $VC2$. In other words, as is traditional in agency theory, we assume that ex ante there is a competitive supply of agents able to take on the role of $VC2$. Throughout the paper, our analysis will focus on the variables ΔR_2 (representing $VC2$'s stake in the project's upside) and $P \equiv F - R_2^L$, which we will interpret as the part of $VC2$'s investment not protected by liquidation preference.

2.1 The symmetric information benchmark

Consider the first-best framework where signals are public and hard information. Then, gathering the second VC's signal is worthwhile if it may induce a change in $VC1$'s decision of whether to fund the project. For the sake of simplicity, throughout the paper we will focus on the case where if $VC1$ observes a bad signal $s_1 = B$, then it is not worth gathering the second VC's opinion. This requires assuming:

$$p(G/B)\,[q(B,G)(H-L)+L-I]-\Psi \leq 0 \tag{$A2$}$$

or:

$$q\theta_2(1-\theta_1)(H-I)+(1-q)\theta_1(1-\theta_2)(L-I)-\Psi[q(1-\theta_1)+(1-q)\theta_1]<0,$$

which imposes that θ_2 is not too large with respect to θ_1:

$$\theta_2 \leq \frac{(1-q)(I-L)\theta_1+\Psi[q(1-\theta_1)+(1-q)\theta_1]}{(1-q)(I-L)\theta_1+q(H-I)(1-\theta_1)} \equiv \overline{\theta}_2(\theta_1)<1.$$

This assumption implies that in a symmetric information context where s_1 is public, $VC1$'s utility is equal to zero when his signal is bad.[9]

Conversely, when $VC1$ has observed a good signal, gathering a second signal is profitable provided the value of syndication is non-negative, i.e.:

$$V_S^{fb} \equiv p(G/G)[q(G,G)(H-L)+L-I]-\Psi \geq 0,$$

or:

$$q\theta_1\theta_2(H-I)+(1-q)(1-\theta_1)(1-\theta_2)(L-I)-\Psi\,[q\theta_1+(1-q)(1-\theta_1)] \geq 0,$$

[9] The incentive problems would be similar if assumption ($A2$) were reversed, but the algebra would be more cumbersome, since in that case $VC1$'s utility when he has a bad signal would be positive and a function of θ_1 and θ_2.

This requires that the second VC has enough expertise to change $VC1$'s initial decision not to invest, as stated in the following:

Lemma 1 *The value of syndication is positive provided VC2's expertise is large enough:*

$$\theta_2 \geq \underline{\theta}_2(\theta_1) \equiv \frac{(1-q)(I-L)(1-\theta_1) + \Psi\left[q\theta_1 + (1-q)(1-\theta_1)\right]}{(1-q)(I-L)(1-\theta_1) + q(H-I)\theta_1} > \frac{1}{2}. \tag{1}$$

The minimum level of VC2's expertise $\underline{\theta}_2$ such that $V_S \geq 0$ decreases with VC1's expertise θ_1.

Notice that if syndication occurs in equilibrium, then it must be the case that the selected syndication partner has $\theta_2 \geq \underline{\theta}_2(\theta_1)$, i.e. condition (1) holds. Casamatta and Haritchabalet (2003) provide a complete taxonomy of VCs' expertise levels ensuring that syndication is profitable in a symmetric information context. We have focused here on the case where $VC2$'s information is valuable (i.e., changes $VC1$'s initial investment decision) only when $VC1$'s signal is good. In our first best benchmark, the threshold $\underline{\theta}_2(\theta_1)$ for $VC2$'s expertise behaves similarly to its analogue in Casamatta and Haritchabalet (2003): when $VC1$ is more confident about his own good signal, even a second (good) signal of low precision is enough to encourage investment. This explains why $\underline{\theta}_2$ is decreasing in θ_1. In the following, we shall argue that even under condition (1), gathering the second VC's opinion may be costly when the VCs' signals are soft information.

3 VCs' incentives and expertise

If the second venture capitalist's evaluation is called for, various incentive issues arise due to the unobservability of private signals. Consider the second VC's information-gathering process. $VC1$ cannot observe whether $VC2$ acquires information or not, hence $VC2$ must be given incentives to gather the signal s_2 at cost Ψ (a standard moral hazard problem). Furthermore, the signal s_2 is soft information. This implies that (i) $VC2$ may not report the signal truthfully to $VC1$ if she has observed one; (ii) $VC2$ may report a signal even if she has not observed one. This last issue has an important effect on the moral hazard incentive constraint for $VC2$.

A further incentive issue arises from the fact that $VC1$'s signal is also manipulable. $VC1$ may be tempted to report a positive signal and propose a syndication contract to $VC2$ even in the case $s_1 = B$. Under assumption (A2), this would imply that $VC2$ is bearing a loss. Hence, $VC2$ will fear that she is "buying a lemon" unless the syndication contract ensures that $VC1$'s report is truthful. In what follows, we first focus on the benchmark case where $VC1$'s signal is public and examine $VC2$'s incentive problems. We will then analyze $VC1$'s incentive problem and see how this alters the contracting possibilities, as well as the desirability for $VC1$ of syndicating with more experienced partners.

3.1 VC2's incentives when VC1's signal is public

The second venture capitalist decides to acquire information provided the following moral hazard incentive constraints hold:

$$p(G/G)\left[q(G,G)R_2^H + (1-q(G,G))R_2^L - F\right] - \Psi \geq 0, \tag{2}$$

that is, gathering the signal s_2 at cost Ψ is better than not gathering it and reporting $s_2 = B$, and:

$$p(G/G)\left[q(G,G)R_2^H + (1-q(G,G))R_2^L - F\right] - \Psi \geq q(G)R_2^H + (1-q(G))R_2^L - F, \tag{3}$$

that is, gathering the signal is better than not gathering it and reporting $s_2 = G$.

The second venture capitalist must also have incentives to report her signal truthfully. If she observes a good signal, $VC2$ must be better off reporting $s_2 = G$ than reporting a bad signal:

$$q(G,G)R_2^H + (1-q(G,G))R_2^L - F \geq 0. \tag{4}$$

If instead the signal observed is bad, $VC2$ must prefer to report $s_2 = B$ rather than reporting a good signal:

$$q(G,B)R_2^H + (1-q(G,B))R_2^L - F \leq 0. \tag{5}$$

It is easy to see that the only relevant constraints are (2) and (3), as these two constraints imply the adverse selection constraints (4) and (5).

Clearly, since $VC1$ is the residual claimant on the returns to the project, he chooses F, R_2^H, and R_2^L so as to minimize $VC2$'s rent:

$$p(G/G)\left[q(G,G)(R_2^H - R_2^L) + R_2^L - F\right] - \Psi$$

subject to constraints (2) and (3). The following proposition describes the set of optimal contracts for $VC1$:

Proposition 1 *When s_1 is public information, after observing a good signal $VC1$ can obtain a second assessment of the project by offering $VC2$ to buy at price F a financial claim with payoffs $\left\{R_2^L, R_2^H\right\}$, such that:*

$$p(G/G)\left[q(G,G)\Delta R_2 - P\right] - \Psi = 0$$

$$q(G)\Delta R_2 - P \leq 0,$$

where $\Delta R_2 \equiv R_2^H - R_2^L$, $P \equiv F - R_2^L$. Each of these contracts is incentive compatible for $VC2$ and leaves her no agency rent.

When his own signal is public, $VC1$ faces a standard principal-agent problem where $VC2$, the agent, must be induced to collect a signal and reveal it truthfully. Gromb and Martimort (2007) provide the solution to this problem for the case where a principal hires one expert as well as that of multiple experts. Our result differs from Gromb and Martimort (2007), where the combination of limited liability, lack of initial wealth and the need to give incentives for information collection means that agents will earn rents. In our model, $VC1$ is able to extract all of $VC2$'s rent via $VC2$'s co-financing of the project. In other words, $VC1$ manages to solve the hired expert's incentive problem *at no cost* by asking her to "put her money where her mouth is". Since $VC1$ can write a contract which allows him to leave $VC2$ no agency rent, $VC1$'s gains from syndication are equal to the project's ex-ante NPV net of the signal collection cost. Hence, $VC1$ will always want to syndicate the deal whenever the value of the additional signal s_2 exceeds its cost Ψ, i.e. whenever the value of syndication V_S^{fb} is positive. This implies that under condition (1) syndication will always occur, and that $VC1$ will always select the most experienced partner:[10]

Corollary 1 ***Value of Syndication and VC2's expertise -*** *A venture capitalist $VC1$ holding a positive and public signal of project profitability always benefits from syndication provided $\theta_2 \geq \underline{\theta}_2$. A syndication deal is signed and the project funded if and only if $VC2$'s assessment is also positive. The value of syndication for $VC1$ is increasing in θ_2, hence $VC1$ always chooses to syndicate with the most experienced partner.*

Figure 1 represents the set of incentive compatible contracts for $VC2$. Contract S corresponds to the pair $(\Delta R_2, P)$ where both constraints are binding, and thus $q(G)\Delta R_2 = P$. It

[10] It also implies that for the hard information case studied in this section, our assumption that $VC1$ would not find it profitable to finance the project on his own (equation $A1$) does not affect our results.

can be easily checked that contract S is defined by:

$$P = \frac{q\theta_1 + (1-q)(1-\theta_1)}{(1-q)(1-\theta_1)(2\theta_2 - 1)}\Psi,$$

$$\Delta R_2 = \frac{q\theta_1 + (1-q)(1-\theta_1)}{(1-q)(1-\theta_1)(2\theta_2 - 1)}\frac{1}{q(\overline{s}_1)}\Psi.$$

One way to implement the above contract is to offer $VC2$ an option to buy preferred stock with senior rights in case of liquidation, while $VC1$ retains common stock (or preferred stock with junior liquidation preference). In many private equity transactions this is the type of deal that lead VCs offer to late VCs. Let $r = R_2^L$ be the minimum revenue to be paid to preferred stock holders, and assume $VC2$ buys at price F a fraction $(1-\alpha) = \frac{R_2^L + \Delta R_2}{H}$ of stock while $VC1$ retains a fraction α in common stock. $VC2$'s claim behaves indeed as preferred stock only if $R_2^L > (1-\alpha)L = \frac{R_2^L + \Delta R_2}{H}L$, that is if R_2^L is relatively large with respect to ΔR_2. Notice that it is often the case that the face value of preferred stock (the amount paid before moving to paying common stock) is close to the cost paid by its holder, i.e. $F - R_2^L$ is small in real life deals.

Liquidation preference and VCs' expertise.
It may be useful to focus on contract S to analyze the impact of an increase in $VC2$'s experience. As in Gromb and Martimort (2007), providing incentives for information gathering to an expert becomes less difficult when the latter has more expertise: when θ_2 is large, low-powered incentives can be given to the second venture capitalist (i.e., ΔR_2 can be low). In our model, this also implies that a more experienced $VC2$ will be asked to provide a smaller share of the funding F, with respect to the payment R_2^L that she receives in case of failure. Another way to interpret this is that a larger fraction of $VC2$'s up front investment is protected by liquidation preference when $VC2$ is more experienced:

$$\frac{\partial P}{\partial \theta_2} < 0.$$

Contract S also varies with $VC1$'s expertise θ_1:

$$\frac{\partial \Delta R_2}{\partial \theta_1} > 0, \quad \frac{\partial P}{\partial \theta_1} > 0.$$

When $VC1$ has more expertise, $VC2$ is more tempted to "free ride" on $VC1$'s signal, and it is more difficult to induce her to gather her own signal s_2. Hence $VC2$'s contract becomes more high-powered and $VC2$ is granted less "liquidation preference" relative to the amount of funding she puts in, (i.e. P is large) when $VC1$ is more experienced.

Remark: Expert's opinion without co-financing. Notice that one of the optimal contracts described in Proposition 1 requires $VC2$ to fund the whole continuation investment ($F = I$) and get full liquidation preference ($R_2^L = L$), while $VC1$ appropriates the project's NPV via the equity stake acquired in the previous financing round. Indeed, in our model, co-financing of late-round investments is unnecessary when the lead VC's signal is public: $VC1$ can obtain a further assessment of the project simply by offering to sell the project to the second VC, so that the latter fully provides the second round of financing. We will show that this is no longer true once $VC1$'s signal is private information: $VC1$ must then participate in the second round of financing to reassure $VC2$ that she is not buying an overpriced claim.[11]

3.2 VCs' incentives when *both* signals are soft information

We now assume that $VC1$'s signal is also non-verifiable and manipulable. $VC1$ may then be tempted to report a positive signal and propose a syndication deal to $VC2$ even when syndication is in fact unprofitable, $s_1 = B$. As a consequence, $VC2$ will fear that she may be buying an overpriced claim unless the contract ensures that $VC1$'s report is also truthful.

Consider the set of contracts described in Proposition 1. When holding a bad signal about the project, should $VC1$ forego the investment or rather propose one of these contracts to $VC2$, claiming he has a positive opinion on the project? If the contract offered satisfies the following condition:

$$q(B,G)(H-L) + L - I - [q(B,G)\Delta R_2 - P] > 0,$$

then $VC2$ may reasonably fear that $VC1$ holds a bad signal. Where does $VC1$'s temptation to misreport a bad signal come from? $VC1$ may not have much confidence in her own assessment and might rather want to rely on $VC2$'s opinion. As the contract makes sure that $VC2$ wants to go ahead only if $s_2 = G$ (i.e. satisfies ((3) and (5)), $VC1$ might want to ask for her opinion and go ahead with the (syndicated) funding whenever $VC2$ reports a good signal, even though $s_1 = B$. Of course, assumption ($A2$) implies that this can never happen when s_1 is public.[12] Thus, it must be the case that $VC1$ is simply trying to sell

[11] This is in line with the corporate finance literature on informational monopolies (Sharpe 1990, Rajan 1992, Petersen and Rajan 1995) whereby outside investors face a winner's curse in financing late stages of a project that a long-term or informed investor has refused to fund.

[12] Indeed, when her signal is public $VC1$ is bound to offer a fairly priced option to $VC2$, conditional on the available information, which implies she cannot appropriate more than the project's ex-ante NPV, net of the signal collection costs, i.e. $p(s_2/s_1)[q(s_1,s_2)(H-L)+l-I]-\Psi$. By assumption ($A2$), the latter is negative when $s_1 = B$ and $s_2 = G$.

an overpriced claim to $VC2$, inflating her own assessment of the project. This incentive for misreporting depends on $VC2$'s expertise in a quite complex way. First, when $VC2$ is a more reliable expert, i.e. when θ_2 is larger, $VC1$ is ceteris paribus more confident that newly issued claims, her own included, will receive high rather than low returns. Thus, she is more tempted to go ahead with the (syndicated) funding even though the expected value of continuation is negative, because she does not have to provide all the financing. Also, when $VC2$'s expertise θ_2 is large, under Proposition 1's contract $VC2$'s stake in the project returns shrinks, which further increases $VC1$'s incentive to go ahead with the funding. However, a more expert $VC2$ also gets a larger part of her investment protected by liquidity preference, according to Proposition 1; $VC1$'s claim is thus diluted more in the downside by the new equity issue, which limits his gains from funding the project when his signal is bad. Hence, the impact of $VC2$'s expertise on $VC1$'s incentive to misreport his signal is not obvious a priori.

A venture capitalist who has privately observed a good signal must find a way of credibly signalling to $VC2$ that his signal is good. Notice that $VC1$ can always guarantee himself his *low information intensity optimum*[13] by offering $VC2$ a menu of two contracts $\{C, C_0\}$ from which $VC1$ will choose ex post, after $VC2$ has accepted the menu. The menu specifies a syndication contract $C = \{\Delta R_2, P\}$ for the "good-signal $VC1$", and the null contract C_0 yielding zero-utility for the "bad-signal $VC1$", which is incentive compatible for $VC1$. As a consequence, $C = \{\Delta R_2, P\}$ must solve:

$$\max_{C} p(G/G)\left[q(G,G)(H - L - \Delta R_2) + L - I + P\right]$$

subject to:

$$p(G/G)[q(G,G)\Delta R_2 - P] - \Psi \geq 0 \qquad (IR_2)$$

$$p(G/G)[q(G,G)\Delta R_2 - P] - \Psi \geq q(G)\Delta R_2 - P \qquad (IC_2)$$

$$q(B,G)(H - L) + L - I - [q(B,G)\Delta R_2 - P] \leq 0. \qquad (IC_1)$$

In this program $VC2$'s moral hazard constraints (2) and (3) have been renamed (IR_2) and (IC_2) respectively. They ensure that $VC2$ gathers her signal, and reveals it truthfully,

[13]See Maskin and Tirole (1992) for the original derivation of this result, and Tirole (2006, appendix to chapter 6) for a more intuitive treatment.

if the menu contract $\{C, C_0\}$ is offered by $VC1$. Constraint (IC_1) makes sure that a lead VC who has observed $s_1 = B$ will optimally choose *not* to start the project at all rather than choose the contract $\{\Delta R_2, P\}$ from the menu. Notice that by construction, VC_2 always breaks even by accepting the option contract $\{C, C_0\}$, independently of what her beliefs are regarding the first VC's private information, because the "bad-signal $VC1$" will not choose contract C. Thus $VC1$ can always guarantee himself the value of the above program. In this paper, we will focus on this low information intensity optimum.[14]

In the low information intensity optimum, either (IC_1) or (IR_2) binds. For low levels of θ_2, (IC_1) does not bind, as at least one of the optimal contracts described in Proposition 1 is incentive compatible for $VC1$. Conversely, for large levels of θ_2, it is (IC_1) which binds, as stated in the following proposition:

Proposition 2 *For any θ_1, there exists a threshold level of expertise $\widetilde{\theta}_2 \in (\underline{\theta}_2, \overline{\theta}_2)$ such that none of the benchmark case contracts is incentive compatible for $VC1$ when $\theta_2 > \widetilde{\theta}_2$. The threshold $\widetilde{\theta}_2$ is always larger than θ_1.*

Proof. See the Appendix. ■

The intuition for this result is simple. When the potential syndication partner has a much larger expertise than the lead VC (i.e., a more precise signal), the latter is more tempted to ask for a second expert evaluation and rely on it for the continuation decision, even when holding a bad profitability signal from previous financing rounds. One can show that the counter-acting effect of $VC2$'s expertise on the shape of her claim is of second-order. When $VC2$'s information is very precise, by falsely reporting his own claim, $VC1$ destroys value by ensuring that the investment in the firm goes ahead, but this destruction of value is relatively small. By contrast, the rents that $VC1$ can gain by mis-reporting his signal and hence selling over-priced claims to $VC2$ can be large. $VC2$ has thus good reason to be suspicious of any contract offer that promises to leave her with zero rent (such as those described in the previous section) since it would be profitable for a "bad-signal $VC1$" to offer such a contract.

Proposition 2 implies that $VC1$ can obtain a second expert evaluation at no agency cost *only if the selected partner is not too experienced.* Conversely, when $VC2$ is very experienced

[14]The low information intensity optimum - which corresponds to the so-called "least-cost separating equilibrium" selected by the Cho-Kreps (1987) intuitive criterion - is the unique Perfect Bayesian equilibrium of the game provided that the probability of $VC1$ having a high signal is below some threshold α^*. When the probability of the high signal is instead very large, it may be more profitable for the high-signal $VC1$ to "pool" with the low signal $VC1$, cross-subsidizing the latter. Since we are interested in contracts which solve the adverse selection problem, we ignore this possibility. Pooling equilibria in this context are not very realistic: they would involve the low-type $VC1$ accepting a payment from $VC2$ *not* to continue the project.

relative to $VC1$, contract C must be distorted away from the benchmark case contracts so as to credibly signal that $s_1 = G$. This requires that $VC1$ contributes enough of the second round funding, and/or that his stake in the project upside is not too large. This implies in turn that $VC2$ enjoys a rent:

Proposition 3 *Whenever $\theta_2 > \widetilde{\theta}_2$, in the low information intensity optimum (contract C) only constraints IC_1 and IC_2 bind, hence $VC1$ has to leave a rent $U_2^* > 0$ to $VC2$. This rent is strictly increasing in θ_2.*

Proof. See the Appendix. ■

It is important to emphasize that in our framework, and in contrast to much of the agency literature, it is the lead VC's informed principal problem, not $VC2$'s agency problem, that generates $VC2$'s rent. More experienced partners enjoy larger rents simply because the lead VC faces a more serious informed principal problem, i.e. he is more tempted to rely on $VC2$'s good signal when he has a bad one. Also, to the extent that a more experienced lead VC is ceteris paribus less tempted to go on with the project after observing a bad signal, a given $VC2$ will receive a smaller rent when syndicating with a more experienced VC.

Our result has the novel implication that late syndication partners can enjoy a rent even though they can supply funding to the project (and thus do not have an ex ante limited liability constraint) and are perfectly competitive. Furthermore, we predict that even in environments where there are plenty of experienced venture capitalists available for syndication, more experienced partners enjoy larger rents. This is consistent with the empirical evidence that more established and larger funds (run by partners with more experience) earn higher returns (see, e.g., Kaplan and Schoar 2005).

3.3 The Shape of Financial Claims

In this subsection we set out our results concerning the comparative shape of financial claims when the incentive constraint IC_1 is binding. Financial claims when IC_1 is slack and instead IR_2 binds are as set out in proposition 1. Note that IC_1 binds more tightly as θ_2 increases: $VC1$ is more tempted to rely on $VC2$'s good signal when the latter is more experienced. To solve the incentive problem, $VC1$ must bear more of the downside risk, so that $VC2$'s net losses in the case of a bad outcome, P, decrease. This can be interpreted as an increase in the liquidation preference which $VC2$ enjoys for a given investment.

4 The choice of a syndication partner

In this section we investigate the lead VC's choice of syndication partner. As argued earlier, in a first best framework the value of syndication is strictly increasing in the level of $VC2$'s expertise (see also Casamatta and Haritchabalet, 2003). This result is unchanged when only $VC2$'s signal is soft information. However, when $VC1$'s incentives are also an issue, it may prove too costly to syndicate with a very experienced partner: $VC1$ may be too tempted to falsely report a good signal and rely on the positive assessment of $VC2$, if the latter has a lot of expertise. This may oblige $VC1$ to distort the syndication contract, leaving a large rent to his partner. The optimal choice of θ_2 thus trades off the benefit of relying on a more precise second assessment of the project with the increased incentive cost of syndication:

$$\frac{dV}{d\theta_2} = q(G)(H-L) + \frac{\partial P(G/G)}{\partial \theta_2}(L-I) - \frac{dU_2^*}{d\theta_2}.$$

Lemma 2 *The value of syndication for $VC1$ is concave in the level of $VC2$'s expertise θ_2 whenever $\theta_1 > q$.*

Proof. See the Appendix. ■

To investigate whether the optimal choice of expertise could indeed be less than the maximum available, we analyze our model numerically.[15] In the example reported here, we set parameter values: $q = 1/2$, $\Psi = 1$, $H = 9$, $L = 2$, $I = 6$, and compute the optimal syndication contract and the value of syndication to $VC1$, $\mathbf{VS}(\theta_1, \theta_2)$, for different pairs (θ_1, θ_2). In line with Proposition 2, all simulations share the feature that, for any given θ_1, $VC1$'s incentive constraint becomes binding for θ_2 sufficiently large, thus shaping the optimal syndication contract. Figure 2 displays for instance the incentive compatible contracts for levels of expertise $\theta_1 = 15/28$, $\theta_2 = 87/99 \cong 0.879$. The optimal contract in the benchmark case is defined by the intersection of the loci IR_2 and IC_2, which lies below the locus IC_1. When $VC1$'s signal is soft information, the optimal contract is defined by the intersection of IC_2 and IC_1, thus leaving $VC2$ with a positive rent. Figure 3 displays the set of incentive compatible contracts for the same parameter values except that a lower level of θ_2 has been chosen ($\theta_2 = 0.825$). In this case, in line with Proposition 2, $VC1$'s incentive constraint does not bind and the optimal contract is the "symmetric information contract" S.

We then study how the value of syndication $\mathbf{VS}(\theta_1, \theta_2)$ varies with $VC2$'s expertise. We set different levels of θ_1 and for each one we check whether $\mathbf{VS}$ is maximized at $\theta_2 = \overline{\theta}_2(\theta_1)$. Indeed, we find that unless θ_1 is large, $\mathbf{VS}$ is maximized at $\theta_2^* << \overline{\theta}_2(\theta_1)$. For instance,

[15] Numerical simulations were performed with the aid of Mathematica.

in the numerical example reported above, we find that $\partial \mathbf{VS}/\partial\theta_2 = -0.064$ at $\theta_1 = 15/28$, $\theta_2 = 8/9 \equiv \overline{\theta}_2(15/28)$. We then state the following:

Proposition 4 *There exists an open set of parameters such that the value of syndication for $VC1$ is maximized at $\theta_2^* << \overline{\theta}_2(\theta_1)$.*

This result contrasts with the predictions obtained in previous papers. In a symmetric information setting the value of syndication for the lead VC is always (weakly) increasing in the quality of $VC2$'s signal. After all, obtaining a more precise additional signal can only improve $VC1$'s investment selection process better. In a setting where only $VC2$'s signal is manipulable, $VC1$ also gains more from syndicating with a more experienced $VC2$, in that a more precise signal improves $VC1$'s investment selection process, and implies a smaller rent for $VC2$, if any. Conversely, in a setting where $VC1$'s signal can be manipulated, syndication becomes less valuable to $VC1$ when θ_2 is very large. This is so because a more experienced $VC2$ will fear more that $VC1$ is trying to sell her an overpriced claim, implying higher incentive costs.

Who syndicates with whom?

Using the same numerical examples, we also investigate the issue of *who syndicates with whom*, and find that the optimal level of $VC2$'s expertise is increasing in θ_1. In Figures 4, 5 and 6 we refer again to parameter values: $q = 1/2$, $\Psi = 1$, $H = 9$, $L = 2$, $I = 6$. We plot $\mathbf{VS}(\theta_2)$ for the following levels of θ_1: $\theta_1 = 0.53$, $\theta_1 = 0.55$, $\theta_1 = 0.57$. The function $\mathbf{VS}(\theta_2)$ is concave and achieves its maximum at, respectively, $\theta_2 \cong 0.855$, $\theta_2 \cong 0.875$, $\theta_2 \cong 0.89$.[16] Our numerical results confirm the prediction found in symmetric information frameworks (Casamatta and Haritchabalet, 2003) that "experienced venture capitalists should syndicate with experienced venture capitalists". Yet, the logic behind the two results is quite different. In Casamatta and Haritchabalet (2003), a very experienced $VC1$ finds it profitable to invest alone after observing a positive signal. Thus, he is ready to syndicate and share the project returns only if this means gathering a very precise signal from $VC2$. In our model, we rule out this explanation by assuming that $VC1$ never wants to invest in the project alone anyway (assumption $A1$). Our result thus relies on the incentive costs of syndication: a very experienced $VC1$ suffers a less serious incentive problem when it comes to revealing his signal to $VC2$; also, this problem is not dramatically worsened when $VC2$'s expertise is increased. This implies that an experienced lead VC does not need to pay a large agency rent

[16]Note that these are all interior solutions, i.e. $0.855 < 0.883 \equiv \overline{\theta}_2(0.53)$, $0.875 < 0.9 \equiv \overline{\theta}_2(0.55)$, and $0.89 < 0.92 \equiv \overline{\theta}_2(0.57)$.

in order to benefit from syndicating with an experienced partner. Note also that proposition 2 implies that in a competitive market, it is never optimal for an experienced VC to choose a second VC who is less experienced than himself. Our results are consistent with the empirical evidence presented in Lerner (1994). Since θ_1 and θ_2 are measures of the precision of the respective VCs' signals, our results also suggest that $VC1$ should be wary of syndicating with a partner who is much more experienced than himself in the particular industry in which the firm operates. This is consistent with the observation that the early-round VCs are more likely to be industry specialists than the later-joiners. Both VCs' signals about the firm should also be more precise the more rounds of financing the firm has already received, suggesting that the issues that we highlight are likely to be more important for relatively early stage firms where asymmetric information is more severe. For firms which are (for example) already generating sales, the choice of syndication partner is likely to be much less critical, which is consistent with anecdotal evidence (for example, the presence of pension funds in late stage syndicates). In contrast to this, if VC1 has financed a firm for several rounds, and yet no hard information about the firm has yet been generated, then it is likely that θ_1 is large relative to the θ_2 of any joining new investor - in this case it will be very difficult for $VC1$ to find any willing syndication partners at any reasonable price (partners will be attracted only if they expect to earn very large agency rents) which could make it difficult for the firm to obtain finance.

5 Concluding remarks

We have analyzed the incentive issues arising when a venture capital syndicate is formed. A lead venture capitalist with a private signal of project profitability seeks the opinion of another venture capitalist before he funds the project. An appropriately designed syndication contract must induce the second VC to gather a profitability signal and reveal it to the lead VC. However, the syndication deal must also ensure that the lead VC's information is credibly signalled to his syndication partner. We studied how the quality of VCs' signals affects the incentive costs of syndication, and conclude that a lead VC who lacks experience may not want to syndicate with a very experienced VC. Even though the latter would collect more useful information about the future returns of the project for the same information collection cost, he will earn an agency rent due to the fact that the inexperienced lead VC would be tempted to sell him what from the lead VC's point of view is a lemon, relying on the good opinion of the joining VC. We showed that when joining VCs get a rent, their investment will tend to be more protected on the downside than would have been granted if a less experienced partner had been chosen.

Our result implies that, even in a competitive market, VCs joining a syndicate who are much more experienced than the incumbent VCs will tend to earn rents (that is, be sold underpriced claims, or, to put it differently, make investments which are small relative to the expected returns). The greater the experience gap, the larger the rent of the joining VC. In addition, we further predict that a VC of given experience will earn lower rents when he joins a syndicate run by a VC whose experience is more commensurate with his own. These results suggest that incumbent VCs should generally prefer to choose syndication partners whose experience level is similar to their own; and we provided numerical simulations showing that indeed, this is the case: more experienced VCs should tend to pick more experienced syndication partners. This prediction is in line with existing empirical evidence (Lerner, 1994).

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6 Appendix

Proof of Proposition 2

We need to show that there exists a threshold $\widetilde{\theta}_2 \in (\underline{\theta}_2, \overline{\theta}_2)$ such that none of the symmetric information contracts is incentive compatible for $VC1$ whenever $\theta_2 > \widetilde{\theta}_2$.

To this aim, it is useful to re-write (IC_1) as

$$V(B,G) - [q(B,G)\Delta R_2 - P] \leq 0, \qquad (IC_1)$$

where

$$V(B,G) \equiv q(B,G)(H-L) + L - I$$

is the ex-post NPV conditional on signals (B,G). From $A2$, we know that at $\overline{\theta}_2$ this ex-post NPV is positive:

$$V(B,G) = \frac{\Psi}{p(G/B)} > 0 \quad \text{if } \theta_2 = \overline{\theta}_2. \qquad (6)$$

It is immediate that there exists a threshold $\widehat{\theta}_2 \in (\underline{\theta}_2, \overline{\theta}_2)$ defined by the equation:

$$V(B,G) = 0,$$

such that $V(B,G) \geq 0$ if and only if $\theta_2 \geq \widehat{\theta}_2$. For all $\theta_2 \geq \widehat{\theta}_2$ it is then: $V(B,G) \geq 0 > V(G)$, implying $q(B,G) > q(G)$.

(i) We show first that at $\theta_2 = \widehat{\theta}_2$ at least one of the symmetric information contracts satisfies IC_1. Consider contract S, i.e. the pair $(\Delta R_2, P)$ such that both IC_2 and IR_2 bind, implying:

$$p(G/G)[q(G,G)\Delta R_2 - P] - \Psi = q(G)\Delta R_2 - P = 0. \qquad (7)$$

When $\theta_2 = \widehat{\theta}_2$, at contract S constraint (IC_1) is slack, as implied by $V(B,G) = 0$ and:

$$q(B,G)\Delta R_2 - P > 0 = q(G)\Delta R_2 - P.$$

(ii) We then show that at $\theta_2 = \overline{\theta}_2$ any symmetric information contract violates $VC1$'s incentive constraint. Indeed, when (IR_2) holds strictly, it is:

$$q(G,G)\Delta R_2 - P = \frac{\Psi}{p(G/G)}. \qquad (8)$$

From $q(B,G) < q(G,G)$, and using the definition of $\overline{\theta}_2$, it follows that at $\theta_2 = \overline{\theta}_2$, any contract $(\Delta R_2, P)$ satisfying (8) also satisfies:

$$V(B,G) - [q(B,G)\Delta R_2 - P] > V(B,G) - [q(G,G)\Delta R_2 - P] = \frac{\Psi}{p(G/B)} - \frac{\Psi}{p(G/G)} > 0,$$

implying that (IC_1) is violated.

(iii) Consider now the $\theta_2 \in (\widehat{\theta}_2, \overline{\theta}_2)$. We ask whether for these levels of θ_2 there exists a contract that simultaneously satisfies (IC_1) and (IC_2), and ensures that (IR_2) binds, i.e.:

$$q(B,G)\Delta R_2 - P \geq V(B,G) \tag{IC_1}$$

$$q(G)\Delta R_2 - P \leq 0 = p(G/G)[q(G,G)\Delta R_2 - P] - \Psi \tag{IC_2}$$

Given the tension between constraints (IC_1) and (IC_2), the ideal candidate is again contract S, which satisfies (7). Indeed, if contract S does not meet (IC_1) then no other symmetric information contract does. Substituting from (7) into (IC_1) we obtain the condition:

$$\frac{q(B,G) - q(G)}{q(G,G) - q(G)} \frac{\Psi}{p(G/G)} \geq V(B,G) \tag{9}$$

We know from above that this condition is met at $\theta_2 = \widehat{\theta}_2$ and violated at $\theta_2 = \overline{\theta}_2$. We can also show that condition (9) is more likely to be violated as θ_2 grows larger. Indeed, manipulating (9):

$$p(G/G)[q(G,G) - q(G)]V(B,G) - q(B,G)\Psi + q(G)\Psi \leq 0,$$

and differentiating the L.H.S. with respect to θ_2 we obtain:

$$\frac{\partial [p(G/G)\,(q(G,G) - q(G))]}{\partial \theta_2} V(B,G) + \frac{\partial V(B,G)}{\partial \theta_2} [p(G/G)\,(q(G,G) - q(G))] - \frac{\partial q(B,G)}{\partial \theta_2} \Psi.$$

It can be easily checked that this derivative is positive. In fact, the first term is positive, whereas the last two terms can be rearranged as:

$$\begin{aligned} \frac{\partial q(B,G)}{\partial \theta_2} [p(G/G)\,(q(G,G) - q(G))\,(H - L) - \Psi] &= \\ \frac{\partial q(B,G)}{\partial \theta_2} p(G/G) \left[V(G,G) - \frac{\Psi}{p(G/G)} - V(G) \right] &> 0. \end{aligned}$$

¿From (i), (ii) and (iii), the proof follows by continuity. We are left to show that $\widetilde{\theta}_2 > \theta_1$. This is immediate: we know that at $\widetilde{\theta}_2$ it is $q(B,G) > q(G)$, implying $\theta_2 > \theta_1$.

Proof of Proposition 3

Contract C can be found by solving the following optimization program (for any given level of θ_2):

$$\min_{\{\Delta R_2, P\}} p(G/G)\,[q(G,G)\Delta R_2 - P]$$

$$\text{s.t.: } IR_2,\ IC_2,\ IC_1$$

.

The Lagrangian for this program can be written as:

$$\begin{aligned} L &= q(G)\theta_2\Delta R_2 - p(G/G)P - \Psi - \lambda_1\left[q(B,G)\Delta R_2 - P - q(B,G)(H-L) - L + I\right] \quad (10)\\ &\quad -\lambda_2\left[-q(G)(1-\theta_2)\Delta R_2 + (1-p(G/G))P - \Psi\right] - \lambda_3\left[q(G)\theta_2\Delta R_2 - p/G/G)P - \Psi\right]. \end{aligned}$$

(i) By Proposition 2 we know that for all $\theta_2 > \widetilde{\theta}_2$, IR_2 cannot bind at the optimum. It is easy to see that both IC_1 and IC_2 will instead bind, hence $\lambda_1 > 0$, $\lambda_2 > 0$, $\lambda_3 = 0$. In fact, the solution where $\lambda_1 = \lambda_3 = 0$ can be excluded: one of the first order conditions would write as:

$$\frac{\partial L}{\partial \Delta R_2} = q(G)\theta_2 + \lambda_2 q(G)(1-\theta_2) = 0,$$

which would imply $\lambda_2 < 0$, a contradiction. Analogously, the solution where $\lambda_2 = \lambda_3 = 0$ can be excluded, as the first order conditions would write as:

$$\frac{\partial L}{\partial \Delta R_2} = q(G)\theta_2 - \lambda_1 q(B,G) = 0, \text{ and } \frac{\partial L}{\partial P} = -p(G/G) + \lambda_1 = 0,$$

implying $p(G/G)q(B,G) = q(G)\theta_2$, which is only verified at $\theta_2 = 1/2$, a contradiction. Hence, when $\theta_2 > \widetilde{\theta}_2$ only the constraint IR_2 is slack (i.e. $\lambda_3 = 0$), whereas IC_1 and IC_2 bind: $VC2$ receives a rent at the optimum.

(ii) To check that $VC2$'s rent is increasing in θ_2, apply the Envelope Theorem to calculate:

$$\frac{\partial L}{\partial \theta_2} = q(G)\Delta R_2 - \frac{\partial P(G/G)}{\partial \theta_2}P + \lambda_1\left[\frac{\partial q(B,G)}{\partial \theta_2}(H-L-\Delta R_2)\right] + \lambda_2\left[-q(G)\Delta R_2 + \frac{\partial P(G/G)}{\partial \theta_2}P\right],$$

which can be rearranged as:

$$\frac{\partial L}{\partial \theta_2} = \lambda_1\left[\frac{\partial q(B,G)}{\partial \theta_2}(H-L-\Delta R_2)\right] + (1-\lambda_2)\left[q(G)\Delta R_2 - \frac{\partial P(G/G)}{\partial \theta_2}P\right]. \quad (11)$$

The first term in (11) is positive as implied by $\lambda_1 \geq 0$, $\frac{\partial q(B,G)}{\partial \theta_2} > 0$, and $H - L - \Delta R_2 \geq 0$ (VCs cannot get decreasing claims). As to the second term, note that:

$$q(G)\Delta R_2 - \frac{\partial P(G/G)}{\partial \theta_2}P = \frac{q\theta_1(\Delta R_2 - P) + (1-q)(1-\theta_1)P}{q\theta_1 + (1-q)(1-\theta_1)} > 0,$$

whereas combining the first order conditions it can be easily shown that $\lambda_2 < 1$ when $q(B,G) > q(G)$, a condition always satisfied at $\theta_2 > \widetilde{\theta}_2 > \widehat{\theta}_2$. This implies that $\frac{\partial L}{\partial \theta_2} > 0$ if $\theta_2 > \widetilde{\theta}_2$. Q.E.D.

Proof of Lemma 2

Applying the Envelope Theorem, it can be shown that:

$$\begin{aligned}\frac{\partial V}{\partial \theta_2} &= q(G)(H-L)+\frac{\partial P(G/G)}{\partial \theta_2}(L-I)-\frac{dU_2^*}{d\theta_2}= \\ &q(G)[H-L-\Delta R_2]+\frac{\partial P(G/G)}{\partial \theta_2}[L-I+P]+ \\ &-\lambda_1\left[\frac{\partial q(B,G)}{\partial \theta_2}(H-L-\Delta R_2)\right]+\lambda_2\left[q(G)\Delta R_2-\frac{\partial P(G/G)}{\partial \theta_2}P\right],\end{aligned}$$

where λ_1 and λ_2 are the Lagrange multipliers of (10).

The Envelope Theorem also implies that:

$$\frac{\partial^2 V}{\partial \theta_2^2}=-\lambda_1\frac{\partial^2 q(B,G)}{\partial \theta_2^2}(H-L-\Delta R_2).$$

As:

$$\frac{\partial^2 q(B,G)}{\partial \theta_2^2}=\frac{2q(1-q)\theta_1(1-\theta_1)(\theta_1-q)}{[q(1-\theta_1)\theta_2+(1-q)\theta_1(1-\theta_2)]^3}$$

is positive provided $\theta_1 > q$, the proof follows.

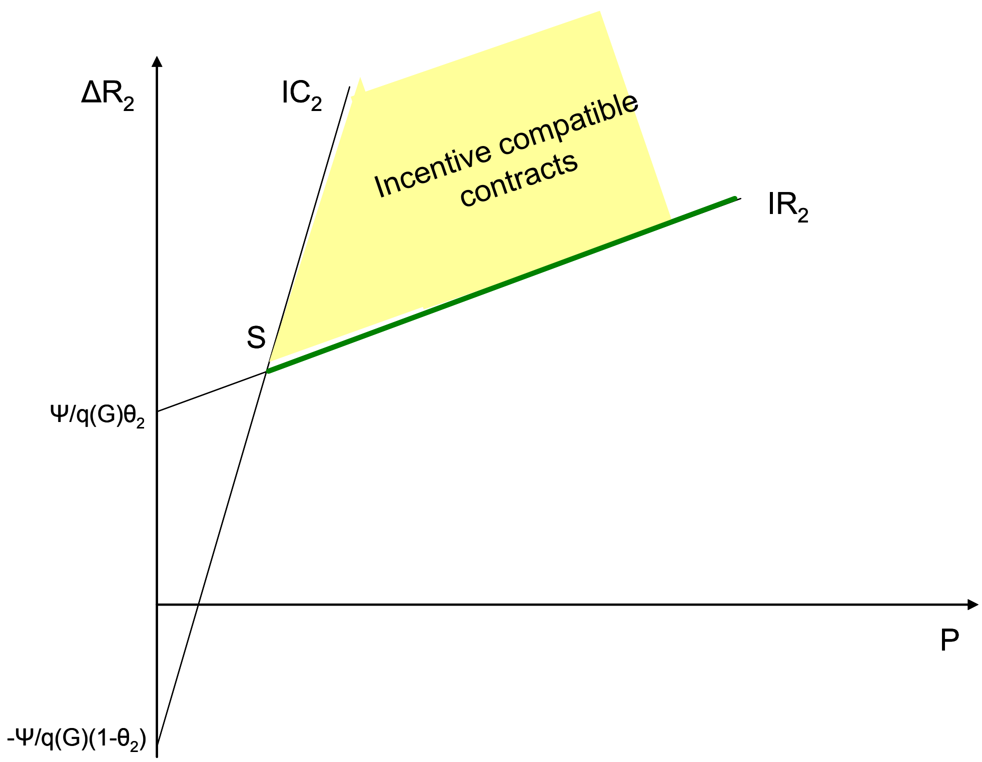


Figure 1: Figure 1 represents the set of incentive compatible contracts in the benchmark case where VC1's signal is public. Contracts above the IR_2 locus satisfy constraint (2), whereas contracts below the IC_2locus satisfy constraint (3). Note that the locus $IC_2$is always steeper than the locus IR_2. The set of optimal contracts includes all the pairs $(\Delta R_2, P)$ situated on IR_2 which lie below the IC_2 line, i.e. the thick segment on the IR_2 line.

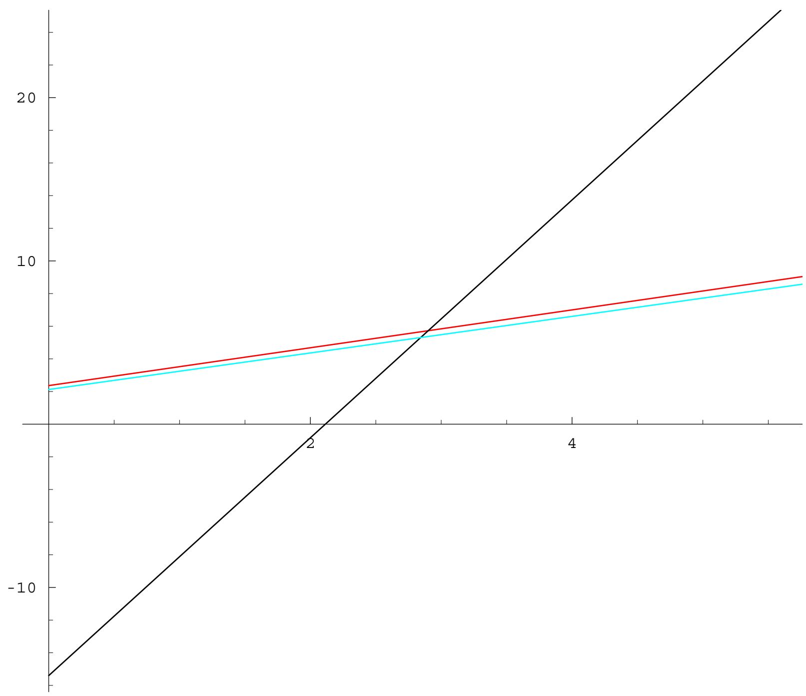


Figure 2: We represent here the set of incentive compatible contracts when VC1's signal is private. The horizontal axis measures P, while the vertical axis measures ΔR_2. Parameter values are as follows: $q = 1/2$, $\Psi = 1$, $H = 9$, $L = 2$, $I = 6$, $\theta_1 = 0.53$, $\theta_2 = 0.88$. Contracts above the flat black line satisfy VC2's incentive constraint (2), while contracts below the steep black line satisfy VC2's incentive constraint (3). The red line represents instead the locus of contracts where $VC1$'s incentive constraint binds: $IC1$ holds for contracts above this line. Notice that none of the benchmark case contracts satisfies $VC1$'s incentive constraint in this example. Hence the optimal contract is determined by the intersection between the red line and the steep black line: $P = 3$, $\Delta R_2 = 5.8$.

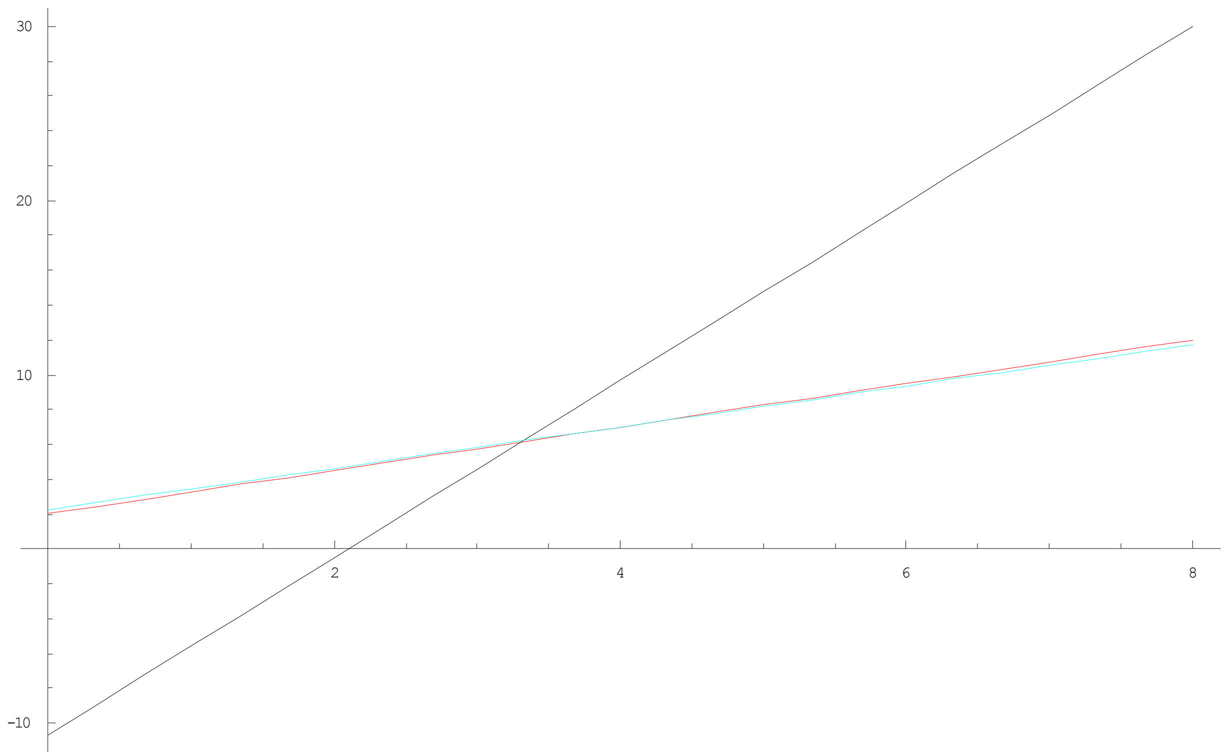
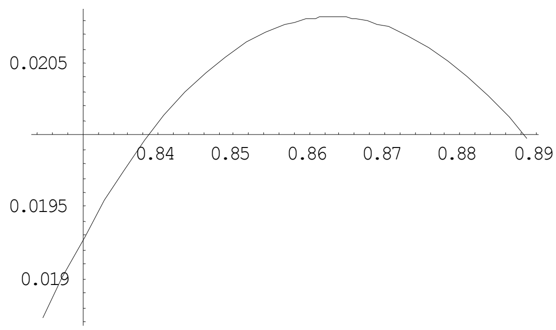
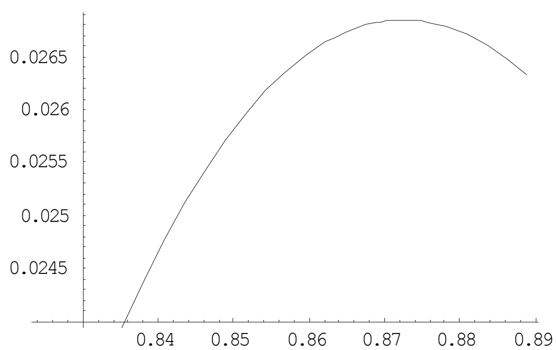


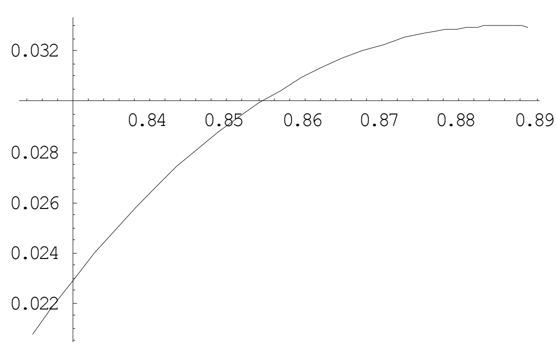
Figure 3: Here the set of incentive compatible contracts is represented for the same values of parameters q, Ψ, H, L, I , θ_1 but for a smaller level of θ_2: $\theta_2 = 0.825$. Notice that in this example the benchmark case contract S lies above the red line, i.e. it does satisfy $VC1$'s incentive constraint. For these parameter values, the optimal contract is then: $P = 3.4$, $\Delta R_2 = 6.2$.



(a)



(b)



(c)

Figure 4: Here the caption