Venture Capital Syndication and Termination of Viable Projects*

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Abstract

Projects financed by venture capital are often syndicated. Syndication has been advocated to be driven by three different hypotheses: a risk sharing, a selection, or a value-added, hypothesis. However, these hypotheses have neglected the possibility for syndication to be driven by the need of reducing competitiveness between otherwise potentially rival projects. To explore this alternative hypothesis, this paper constructs a model where venture capitalists financing projects that are competing to varying degrees decide whether to syndicate and, thus, terminate one of the projects. Venture capitalists take the decision whether to syndicate after a signal about the quality of the projects is observed. We show that if these signals are public, syndication occurs out of competition concerns and viable projects with a good signal will be terminated. This leads to a possible reduction in expected social welfare. We then proceed to show that if signals are private, venture capitalists do not always have incentives to truthfully reveal their signals and, as a result, may syndicate less often. This is likely to lead to welfare improvements over the situation with public signals.

Keywords: venture capital, syndication, competition, termination, innovation, public and private signals

JEL classification: C7, D21, D82, G24, L2, M13, O3

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1 Introduction

Venture capital financing plays an important role in innovation since entrepreneurs have ideas, but they often do not have the funds to turn them into innovations. Hence, they need to convince venture capitalists of their values to obtain any venture capital financing to develop further their ideas for the final market.

In the venture capital industry, firms often syndicate their investments. Wright and Lockett (2003) report that in 2001, about 60% of venture capital investments were syndicated in the US and about 30% were syndicated in Europe. According to Schwienbacher (2002), an average syndicate involves 4.5 venture capitalists in the US and 2.7 venture capitalists in Europe. Lerner 1994 reports that in the US, first-round investments are syndicated on average by 2.2, second-round investments by 3.3, and third-round investments by 4.3 venture capitalists. There is also evidence that syndicates invest significant amounts in younger firms, in earlier rounds, and in earlier stages of a firm's life cycle (Tian, 2007).

Three common reasons given for syndication are risk sharing, managerial value added, and project selection (e.g., Lerner, 1994; Brander, Amit and Antweiler, 2002; Hopp and Rieder, 2003; Casamatta and Haritchabalet, 2007; Cestone, Lerner and White, 2007). In addition, Bachmann and Schindele (2006) show that syndication can be a potential solution to the theft of ideas by venture capitalists, and Dorobantu (2006) shows that syndication can be used by the venture capitalists to signal their project-selection ability to other potential investors.

In this paper, we explore an alternative rationale for syndication that derives from the elimination of potentially rival ideas. We consider a model where entrepreneurs with different ideas seek financing from venture capitalists. The venture capitalists prior to deciding whether to invest in the ideas and whether to syndicate their investments receive signals about the quality of the ideas. We allow for signals to be either public or private. We assume that if multiple ideas targeting the same market niche are invested in and are successful, there are competing innovations in the market. Although both ideas can be patented, each would be earning less than monopoly profits.

Under public signals, our results reveal that venture capitalists have incentives to syndicate and terminate investment in competing ideas. This happens even in cases when both venture capitalists received favourable signals regarding the quality of the ideas, provided that the level of investment required to develop the initial idea is sufficiently low. In such cases, syndication is detrimental to social welfare because it results in a reduction of competition. If the investment cost is sufficiently high, one of the venture capitalists drops out and syndication is not a stable outcome.

Under private signals, we show that the results change in two important ways. First, since venture capitalists cannot send credible messages when signals are private, welfare-reducing syndication happens less frequently. Second, if both venture capitalists receive bad signals, welfare may be reduced since both venture capitalists abandon their ideas when signals are private while only one abandons when signals are public.

The rest of the paper is organized as follows. Section 2 describes the setup of the model. Section 3 deals with the analysis of the public signals case, characterizing the equilibrium configurations for the investment into ideas by venture capitalists. Section 4 focuses on the analysis of the private signals case, checking for the venture capitalists' incentives to transmit their private information truthfully, then explores the alternative equilibria when those incentives are violated, and, finally discusses the implication for social welfare of privately acquired signals versus publicly acquired ones. Section 5 concludes.

2 The model setup

Consider a potential market for which two risk neutral entrepreneurs have each an idea for a product. Assume that, were both products introduced into that market, they would be competing with each other. In order to become commercializable final products, both ideas require further investment of size $I \in \mathbb{R}_+$ into their development. With the investment, an idea can succeed or fail. The probability of success is $\Pr(good) := p \in [0,1]$ and the probability of failure is $\Pr(bad) := 1-p$. Assume each project's success to be independent of the other's. Lacking the means for the investment, entrepreneurs need to team up with one of 2 risk neutral venture capitalists, VC_i, where $i = 1, 2$, in order to develop their respective idea.

Assume that entrepreneurs are currently matched with one venture capitalist each, who need to decide whether to finance (further) development. For simplicity, assume that entrepreneur 1 is matched to venture capitalist 1 and entrepreneur 2 is matched to venture capitalist 2. Before deciding about the investment, venture capitalist i receives a signal $s_i \in \{g, b\}$ from her involvement in venture i, where g stands for a good signal and b for a bad one.[1]

Signals are assumed to be correct with probability $a \in \left[\frac{1}{2}, 1\right]$, i.e., $a := \Pr(s_i = g|\, good) \equiv \Pr(s_i = b|\, bad)$. The parameter a can also be interpreted as the precision of the signal.[2] In addition to the independence of the projects' successes, also assume that the signals' imperfections are independent of each other. This implies that it is not possible to learn about project 1's success from a signal about project 2 and vice versa. Consider two alternative assumptions regarding the observability of the signals. First, consider the case of *public* signals, where each venture capitalist can perfectly observe not only the signal of her own project, but also the signal of the other venture capitalist. Second, consider the case of *private* signals.

[1] Without substantial change in the results, one could alternatively assume that entrepreneurs are not currently matched with a venture capitalist. Instead, one could assume that they approach venture capitalists and can receive an initial financing agreement from one venture capitalist and that each venture capitalist finances at most one of the two competing projects (Interviews with venture capitalists confirmed that financing of competing projects does not happen in practice as entrepreneurs are afraid of theft of their often unprotected ideas and of potential conflicts of interest). When venture capitalist i is approached, she scrutinizes the entrepreneur's business plan and receives a signal $s_i \in \{g, b\}$ about the quality of the proposed investment opportunity, where g stands for a good signal and b for a bad one.

[2] Alternatively, it can be interpreted as the ability for venture capitalists to assess the likelihood of success of their ideas. The more precise the results of their due-diligence process, the higher the degree of reliability of the signal. A perfect assessment can be thought of as a perfectly informative signal: a negative assessement - a bad signal in our model - would imply that the idea fails with certainty; while a positive assessement - a good signal in our model - would imply that the idea will succeed for sure.

Here, the signal is revealed only to the venture capitalist who has followed the project in the past[3] and it is non-verifiable and manipulable.[4] Upon observing the signal for a particular project, a venture capitalist updates the probability of success of that project following Bayes' rule. Label the ex-ante probability of getting a good signal as σ_g, with $\sigma_g = ap + (1-a)(1-p)$, and the ex-ante probability of getting a bad signal as σ_b, with $\sigma_b = (1-a)p + a(1-p)$. Then it is possible to write the updated probability of success of a project given that a good signal has been observed, denoted p_g, as $p_g := \Pr(good|\, s_i = g) = \frac{ap}{\sigma_g}$ and the updated probability of success of a project given that a bad signal has been observed, denoted p_b, as $p_b := \Pr(good|\, s_i = b) = \frac{(1-a)p}{\sigma_b}$.

Once signals are obtained, and the ex-ante probabilities of success and failure updated accordingly, venture capitalists face three possible choices: They can either *Continue* on their own, C, and invest the amount I into the development of their entrepreneur's idea; they can choose not to invest into the development of their entrepreneur's idea and *Terminate* their relation with the entrepreneur, T; or they can approach the venture capitalist with the competing project and suggest syndication. If both agree on that, they syndicate, S, the development of *one* of the ideas and terminate the other one.[5]

If two venture capitalists chose C and both succeeded with their development, the products would compete in the market place and the venture-backed firms would enjoy duopolistic profits, π^D. If only one project succeeds, the venture-backed firm bringing it to the market (be it backed by one venture capitalist or both venture capitalists within a syndicate) would enjoy monopolistic profits, π^M. We assume $2\pi^D \leq \pi^M$.[6] We will frequently refer to the situation where $\pi^D = 0$ as *strong competition* and to the situation where $\pi^D = \frac{\pi^M}{2}$ as *lax competition*.

We could assume that there were more than two ventures capitalists competing to finance the entrepreneurs, who, irrespective of the observability of the signals, all observe the choices of the two venture capitalists involved, i.e., whether an entrepreneur's project has been terminated/rejected by a venture capitalist, and who also observe whether the competing project has been syndicated. If a project has been terminated, another venture capitalist would, therefore, be able to "pick up" and finance the project. However, as long as the two syndicating partners are able to keep both entrepreneurs to follow one of their ideas, this does not provide real competition and results do not change.

In sections 3 and 4 we analyze each of those alternative choices, respectively for the public and private signals case.

[3] With the alternative interpretation, it is revealed only to the venture capitalist who scrutinized the business plan.

[4] Note that whether signals are reliable or not, is not incompatible with signals being either public or private.

[5] We choose this for simplicity of exposition. We could allow for the endogenous continuation of both projects in the syndicate, however, as will be clear later on, this will not affect the quality of our results.

[6] We take this assumption, as we want to explore the incentives for syndicating ideas when they are rival. It would not hold, for example, if ideas were to be developed for completely separated markets in which each venture was to enjoy a monopoly.

3 Analysis: Public Signals

Assume that the signal one venture capitalist receives can also be observed by the other venture capitalist. Then the expected payoffs, as a function of the two venture capitalists' choices, can be written as follows.

Competition (C,C) If both venture capitalists develop their ideas, we denote this case as (C, C), and we can write the expected profits accruing to venture 1, $\Pi_1(C, C)$, as

$$\Pi_1(C,C) = \begin{cases} p_g^2\pi^D + p_g\left(1-p_g\right)\pi^M - I & \text{if } (s_1,s_2)=(g,g) \\ p_g p_b \pi^D + p_g\left(1-p_b\right)\pi^M - I & \text{if } (s_1,s_2)=(g,b) \\ p_b p_g \pi^D + p_b\left(1-p_g\right)\pi^M - I & \text{if } (s_1,s_2)=(b,g) \\ p_b^2\pi^D + p_b\left(1-p_b\right)\pi^M - I & \text{if } (s_1,s_2)=(b,b) \end{cases},$$

and the one of venture 2 in a similarly.

Assume that (1) the net present value (NPV) of competing on the market after investing into ideas that both received bad signals is negative and that (2) the expected profit of being a monopolist developing a project with a good signal is positive:

Assumption 1 $p_b^2\pi^D + p_b\left(1-p_b\right)\pi^M \leq I < p_g\pi^M$.

Note that this assumption also implies $p_b p_g \pi^D + p_b\left(1-p_g\right)\pi^M \leq I$ and $p_b p \pi^D + p_b\left(1-p\right)\pi^M \leq I$.

Thus, assumption 1 implies that it is unprofitable for a venture capitalist who received a bad signal to pursue a project in competition with another venture capitalist, irrespective of the signal received by the other venture capitalist.

Termination of one Idea (C,T) or (T,C) If one venture capitalist pursues the investment into the initial idea, while the other one does not, we denote this case as (C, T), or (T, C) depending on whether VC_2 or VC_1 respectively abandons their investment. We can summarize these expected payoffs, w.l.o.g. for VC_1, as follows:

$$\begin{cases} \Pi_1(C,T) = p_g\pi^M - I & \text{if } (s_1,s_2)=(g,\cdot) \\ \Pi_1(C,T) = p_b\pi^M - I & \text{if } (s_1,s_2)=(b,\cdot) \\ \Pi_1(T,C) = 0 & \text{if } (s_1,s_2)=(\cdot,\cdot) \end{cases}$$

By assumption 1, we know it is not profitable for the venture capitalist who receives a bad signal to compete against a rival who got a good signal. In this case, the venture capitalist who received the bad signal drops out and the one who received a good signal continue alone. However, if both venture capitalists receive the same signals, but competition is not viable, then there are two equilibria, (C, T) and (T, C). In this case, we assume that each equilibrium is played with probability $\frac{1}{2}$.

Syndication (S) If competition, (C, C), is feasible, venture capitalists have the choice of whether to compete or to syndicate their investments. If venture capitalists choose to syndicate their investments, (S), we assume that one idea is dropped and only one is pursued for further development for the market. We assume that the dropped project cannot be pursued by a competitor.[7] We also assume that the venture capitalists bargain over the incremental surplus with equal bargaining power. That means that the expected pay-off received by each venture within the syndicate is equal to the sum of (i) the venture's competition payoff and (ii) half the incremental surplus created by the syndicate over the competition surplus.

Given assumption 1, competition is not feasible if one of the ventures received a bad signal and syndication can be an equilibrium only if both signals are good. In this situation, bargaining over the incremental surplus with equal bargaining power means that the syndication profit is shared equally:

$$\Pi_i(S) = \frac{1}{2}\left(p_g \pi^M - I\right) \qquad \text{if } (s_1, s_2) = (g, g).$$

Not that with this setup, we distinguish between the abandoning of an idea that is dictated by competition concerns, i.e., to avoid competition which would be chosen otherwise; or by feasibility concerns, i.e., to avoid negative profits from competition even if they both projects received good signals. In this model, when we refer to *syndication*, we focus on the decision to drop one idea out of *competition concerns*.

3.1 Equilibrium Configurations of Ventures

We can now compare the expected payoffs in each of these three scenarios and determine the equilibrium configurations chosen by venture capitalists for each combination of the received signals. This equilibrium configuration depends on the ex-ante probability of success, the signal received and its precision, the monopoly and duopoly profits, as well as the size of the investment necessary to develop the project into a commercializable product. We depict the equilibrium configurations graphically (and algebraically) as a function of the investment size. There will be cut-off points for the investment level I below which, competition is preferred to syndication, and above which the opposite is true, as well as threshold levels of I above which continuation by one venture capitalist alone is dictated by negative profits in competition and below which the opposite is true.

Across all the three possible combinations of signals, (g, g), (g, b) or (b, g), and (b, b), we identify five mutually exclusive sub-cases for the equilibrium configurations of the ventures. We label those cases with progressive Roman numbers, $(i) - (v)$. Figures 1-5 below highlight the equilibrium configurations of ventures for each of the five identified cases. Note by now, that the conditions to be in each of the subcases will be a function of $\frac{\pi^M}{\pi^M - \pi^D}$, a, and p.

Case (i)

Assumption 2 $p_g \pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b \pi^M - p_b^2\left(\pi^M - \pi^D\right)$.

[7] A reason for this could be that pursueing the project requires tacit knowledge of the entrepreneur, who is kept within the venture-backed firm.

Figure 1 shows the equilibrium configurations of ventures for the public signals case if assumption 2 holds, i.e. iff $\frac{\pi^M}{\pi^M-\pi^D} < p_g + p_b$:

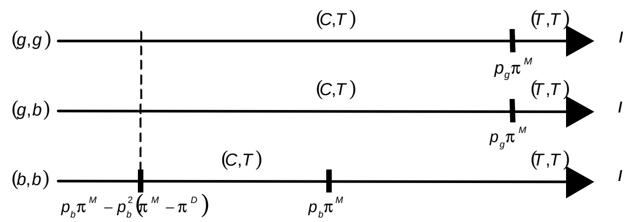

Figure 1: Case (i): $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$

In this case, competition is never viable and at least one of the venture capitalists drops the project in order to avoid negative profits. We describe the characteristics of the equilibrium configurations of the ventures for this subcase in lemma 2 (see Appendix A).

Note that, following the assumption $2\pi^D \leq \pi^M$, $\frac{\pi^M}{\pi^M-\pi^D} \in [1, 2]$. Note also that the condition to be in subcase (i), $\frac{\pi^M}{\pi^M-\pi^D} < p_g + p_b$, is a function of only $\frac{\pi^M}{\pi^M-\pi^D}$, p, and a. We can therefore, characterize the combinations of a and p for which we are in subcase (i) for any $\pi^D \in \left[0, \frac{\pi^M}{2}\right]$. For strong competition, i.e., for $\pi^D = 0$, $\frac{\pi^M}{\pi^M-\pi^D} = 1 < p_g + p_b \Leftrightarrow p > \frac{1}{2}$, $\forall a \in \left[\frac{1}{2}, 1\right[$. This means that as long as the ex-ante probability of success of ideas is sufficiently high and competition is very strong we are in subcase (i). For lax competition on the other hand, i.e., for $\pi^D = \frac{\pi^M}{2}$, $\frac{\pi^M}{\pi^M-\pi^D} = 2 > p_g + p_b$, $\forall a \in \left[\frac{1}{2}, 1\right[$ and $\forall p \in [0, 1]$. This implies that for lax competition we are never in subcase (i).

Similarly we will be able to depict the a and p combinations for which the other cases occur for any $\pi^D \in \left[0, \frac{\pi^M}{2}\right]$. Figures 6 and 7 below will combine the regions in the $p - a$ space that are compatible with each case to occur, respectively for strong and for lax competition in the final market of the developed ideas.

Case (ii)

Assumption 3 $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M$.

Figure 2 shows the equilibrium configurations of ventures for the public signals case if assumption 3 holds instead, i.e. iff $p_g + p_b < \frac{\pi^M}{\pi^M-\pi^D} < \frac{p_g^2}{p_g-p_b}$:

Similarly to case (i), we describe these equilibrium configurations of the ventures for case (ii) in lemma 3 (see Appendix A).

Case (iii)

Assumption 4 $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ *and* $p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$.

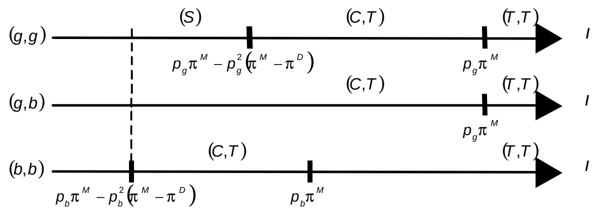

Figure 2: Case (ii): $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M$

Figure 3 shows the equilibrium configurations for the ventures when assumption 4 holds, i.e. iff $\frac{p_g^2}{p_g - p_b} < \frac{\pi^M}{\pi^M - \pi^D} < (p_g + p_b) + \frac{p_g^2}{p_g - p_b}$:

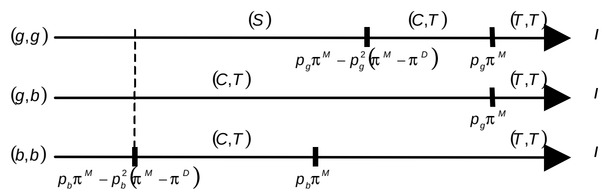

Figure 3: Case (iii): $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$

In lemma 4 the equilibrium configurations of the ventures for this case are described (see Appendix A).

Case (iv)

Assumption 5 $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$.

Figure 4 shows the equilibrium configurations for the ventures when assumption 5 holds, i.e. iff $(p_g + p_b) + \frac{p_g^2}{p_g - p_b} < \frac{\pi^M}{\pi^M - \pi^D} < \frac{2p_g^2}{p_g - p_b}$:

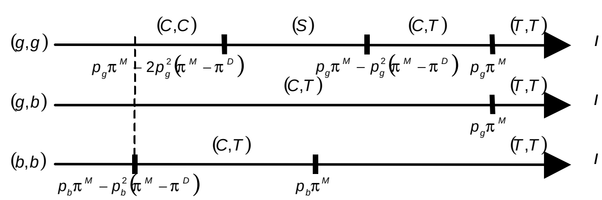

Figure 4: Case (iv): $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$

Lemma 5 describes the equilibrium configurations of the ventures for this case (see Appendix A).

Case (v)

Assumption 6 $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$.

Figure 5 shows the equilibrium configurations for the ventures when assumption 6 holds, i.e. iff $\frac{2p_g^2}{p_g - p_b} < \frac{\pi^M}{\pi^M - \pi^D}$.

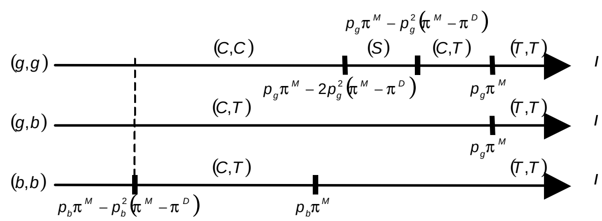

Figure 5: Case (v): $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$

Lemma 6 describes the equilibrium configurations of this subcase (see Appendix A).

Cases (i) - (v) We now summarize for which $a - p$ combinations each of the cases arises for strong and lax competition, represented in figures 6 and 7. This representation will be useful when we study the impact of private signals.

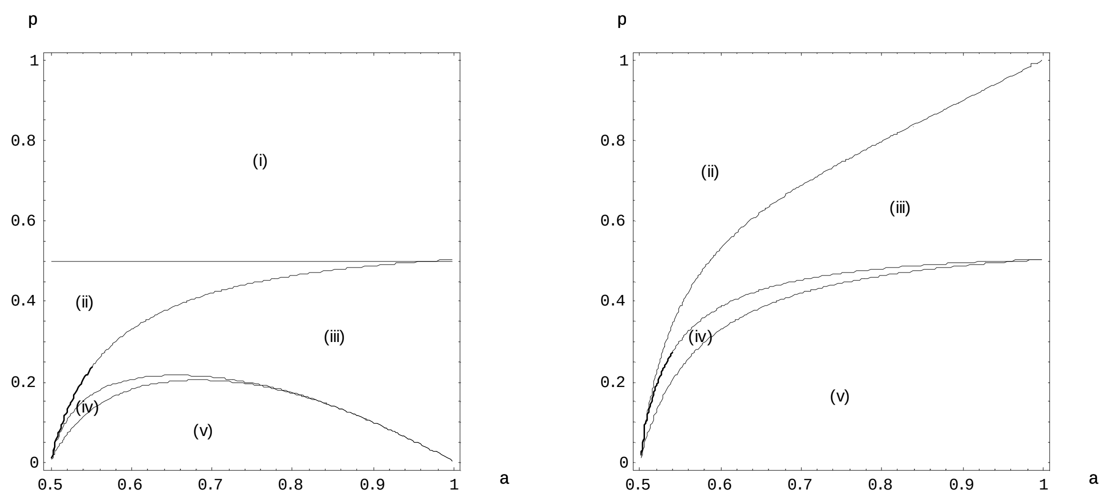

Figure 6: Cases $(i) - (v)$ for strong competition (left panel), i.e. $\pi^D = 0$, and for lax competition (right panel), i.e., $\pi^D = \frac{\pi^M}{2}$, as a function of p and a.

As for now, we can summarize the results for the public signals case as follows:

Remark 1 *For the public signals case, in $(s_1, s_2) = (b, b)$, that is if both venture capitalists receive bad signals, only one of them terminates as long as the other one is viable as a monopoly (in other words, as long as the level of the required investment into the development of the idea is not too high), and both terminate otherwise.*

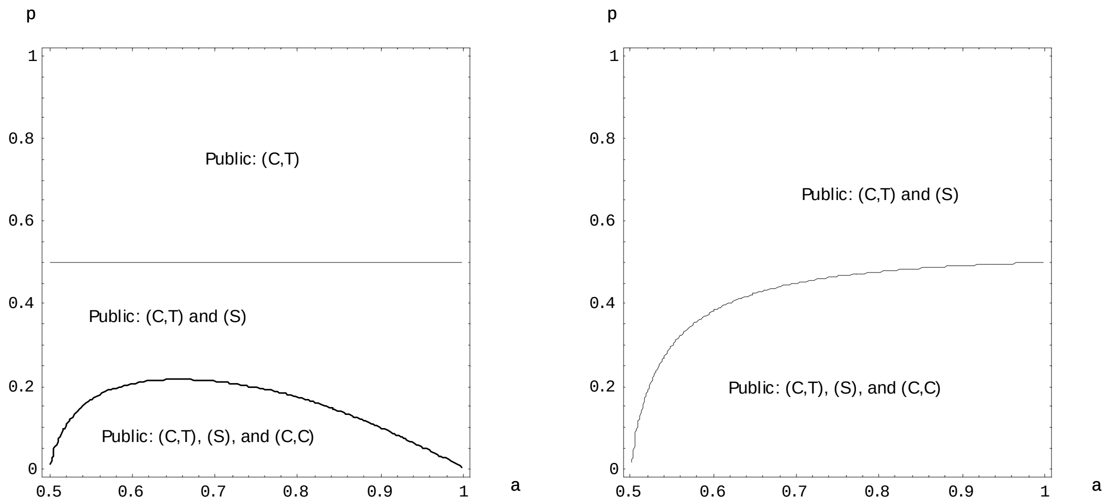

Figure 7: Equilibrium organizations for strong competition (left panel), i.e. $\pi^D = 0$, and for lax competition (right panel), i.e., $\pi^D = \frac{\pi^M}{2}$, as a function of p and a. (C,T) occurs for the highest I, and (C,C) for the lowest.

Remark 2 *For the public signals case, in $(s_1, s_2) = (g, b)$ or in $(s_1, s_2) = (b, g)$, that is if one venture capitalist receives a bad signal and the other one a good one, only the one with the good signal continues, as long as the level of the required investment into the development of the idea is not too high.*

Proposition 1 *For the public signals case, suppose $(s_1, s_2) = (g, g)$, that is that both venture capitalists receive a good signal. Then, in equilibrium,*

(i) if $p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < I < p_g \pi^M$, only one venture capitalist continues to invest while the other one drops out;

(ii) if $p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right) < I < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right)$, the venture capitalists syndicate and invest in only one of the projects; and

(iii) if $I < p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right)$, both venture capitalists continue to invest.

Part of these results follow directly from assumption 1 that we made concerning the viability of the investments; however, which configurations are preferred in particular for the combination of the signals $(s_1, s_2) = (g, g)$ has been derived endogenously. We expressed it as a function of the ex-ante probability of success, the precision of the signal, and the level of competition venture capitalists face in the final market.

Assuming public signals about the likelihood of success of the ideas, our results show that if both venture capitalists receive good signals,

1. in high competition environments (p high, π^D small) one venture capitalist drops out whereas the other one continues as long as the investment cost is sufficiently high;

2. as competition eases (p falls, π^D increases), venture capitalists syndicate low investment ideas, whereas one drops for high investment costs;

3. as competition eases further, both venture capitalists continue on their own for low investment costs, they syndicate for intermediate investment costs, and one venture capitalist drops out for high investment costs.

3.2 Welfare Implications of Syndication

We already discussed that a necessary condition for syndication to be chosen is that venture capitalists both receive good signals. However, the rationale for syndication goes beyond this initial observation. In order to have syndication, there need to be intermediate levels of competition, not too high ex-ante probabilities of success, p, not too small duopolistic profits if competition, π^D, and low or intermediate levels of the investment costs required to develop the idea for the final market.

Syndication, which is chosen for levels of investment for which competition would have been viable otherwise, has been distinguished from the situation in which both ideas would not be viable in competition. Our results show that syndication, thus, entails the socially undesirable outcome that good ideas are abandoned and no further investment into their development for the final market is made.

Assume consumers surplus in monopoly to be strictly less than in duopoly. Then, for investment levels, for which VCs syndicate, and which are close to investment levels for which both would have continued with their projects separately, the VCs' syndication decision implies a welfare loss over competition. The reason is that at $I = p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$, VCs are indifferent between (S) and (C, C) but consumer surplus is strictly larger in (C, C) than in (S). While it raises the profit difference between (S) and (C, C) continuously from zero, increasing the investment necessary for the development of the innovation will not change this difference in consumer surplus. Thus, as long as the profit difference is smaller than the consumer surplus difference, the syndication decision is welfare decreasing as compared to stand-alone development.

4 Analysis: Private Signals

The public signals environment has provided us with a benchmark for analyzing the more complex situation where non-verifiable and manipulable signals are instead privately acquired by venture capitalists. In this section of our analysis, we verify whether the social welfare decreasing effect will be mitigated or exacerbated whenever venture capitalists cannot observe each others' signals, as signals are privately acquired, non-verifiable and manipulable. We first explore whether venture capitalists have an incentive to truthfully reveal their signals to each other if that means that the public signals equilibrium would be implemented. We show as a function of the parameters of the model that they have an incentive to manipulate them. We then solve for symmetric Perfect Bayesian Equilibria (PBE) for the parameter regions in which truthtelling is not an equilibrium. We find that in these symmetric PBE, venture capitalists do not syndicate where they would have competed with public signals. On the contrary, they compete where they would have syndicated with private signals.

Let us start by assuming that after receiving a private signal about the ideas to be invested into, each venture capitalist can simultaneously send to the each other a non-verifiable message, m_i, with $m_i \in \{g, b\}$, which is intended to convey information about the quality of the privately acquired signals. As long as truthful revelation by venture capitalists is incentive compatible, the equilibrium configurations obtained when signals are public can also be implemented under private signals. Thus, we are interested in testing whether there is a scope for those incentive compatibility constraints to be violated, and if so which alternative equilibria can be expected instead.

If venture capitalists have an incentive to lie with respect to the nature of their true signal, messages cannot be trusted and become uninformative. Thus, each venture capitalist will have to reason in expectation regarding the signal received by the other one when deciding which configuration of venture to adopt or to agree upon. We will resort to the PBE as the solution concept when incentive compatibility constraints are violated and we will study their existence for each of the cases $(i) - (v)$ as identified in the public signals case in order to compare them, and then discuss the welfare implications of syndication for these alternative environments.

We start by exploring whether there are profitable unilateral deviations from the truthtelling behavior. For that, we compare the payoff a venture capitalist receives when telling the truth, provided the other says the truth, with the payoff obtained by lying, still provided the other one says the truth. If the payoff from lying is superior to the one by telling the truth, the incentive compatibility constraint is violated and messages cannot be trusted. We perform this analysis for each of the subcases $(i) - (v)$ identified earlier.

4.1 Truthtelling Incentive Compatibility Constraints

Case (i) Remember that in this case, assumption 2, $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$, holds, i.e. $\frac{\pi^M}{\pi^M - \pi^D} < p_g + p_b$. It can be shown that for $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$, a venture capitalist with a bad signal has an incentive to mimic one having a good signal. For $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$, (a) a good message cannot be trusted, (b) a bad message will not be sent, and (c) venture capitalists have to discard messages in equilibrium. For $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M < I < p_g\pi^M$, venture capitalists would not have an incentive to send a false signal.

These results are represented graphically in figure 8, where the dark grey area accounts for the interval of the investment costs for which the incentive compatibility constraint to send truthful messages is violated.

These intermediate results have been obtained as follows. Let us assume, first that $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$. Under public signals, irrespective of the signal combination, one of the venture capitalists would

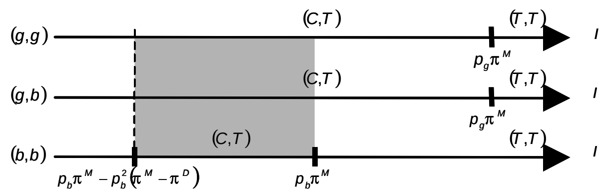

Figure 8: Case (i): $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$

have terminated the project, whereas the other one would have continued.

Let $s_1 = g$. Then with probability σ_g, also $s_2 = g$, and the venture capitalists flip a coin to determine who continues and earns monopoly profits.[8] Maintaining the assumption that $s_1 = g$, if $s_2 = b$, which happens with probability σ_b only VC_1 will continue the idea alone. Thus, taking as given that the other venture capitalist sends a truthful message, by receiving a good signal and transmitting a truthful message as well, i.e. $s_1 = g$ and $m_1 = g$, VC_1 would get:

$$\sigma_g \frac{1}{2}\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right).$$

If instead $s_1 = g$, but $m_1 = b$, then, provided VC_2 sends a truthful message, VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \frac{1}{2}\left(p_g\pi^M - I\right).$$

As $\sigma_g \frac{1}{2}\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right) > \sigma_b \frac{1}{2}\left(p_g\pi^M - I\right)$ the incentive compatibility constraint not to lie holds. If instead $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \frac{1}{2}\left(p_b\pi^M - I\right)$$

And, if $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_b\pi^M - I\right) + \sigma_b\left(p_b\pi^M - I\right)$$

As $\sigma_g \frac{1}{2}\left(p_b\pi^M - I\right) + \sigma_b\left(p_b\pi^M - I\right) > \sigma_b \frac{1}{2}\left(p_b\pi^M - I\right)$, the incentive compatibility constraint not to lie is violated.

Assume now that $p_b\pi^M < I < p_g\pi^M$. Under public signals, with (g, g) and (g, b) or (b, g), one of the venture capitalists would have terminated the project, whereas the other one would have continued. With (b, b), both would have terminated. If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right).$$

If $s_1 = g$ but $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b\left(p_g\pi^M - I\right).$$

[8] Remember that σ_g and σ_b are respectively the probabilities of getting either a good or a bad signal.

As $\sigma_g \frac{1}{2}\left(p_g \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right) > \sigma_b \left(p_g \pi^M - I\right)$, the incentive compatibility constraint not to lie holds. If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

Also for this case, there is no incentive to lie about the nature of the signal.

We see that for $p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < I < p_b \pi^M$, a venture capitalist with a bad signal would have an incentive to lie.

Case (ii) Remember that for this case assumption 3, $p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M$, holds, i.e. $p_g + p_b < \frac{\pi^M}{\pi^M - \pi^D} < \frac{p_g^2}{p_g - p_b}$.

It can be shown that for $p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M$ and $p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < I < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right)$, a venture capitalist with a bad signal has an incentive to mimic one having a good signal. This means that, for $p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M$ and $p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < I < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right)$, (a) a good message cannot be trusted, (b) a bad message will not be sent, and (c) VCs have to discard messages in equilibrium. For $p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M$ and $p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < I < p_b \pi^M$, a venture capitalist with a bad signal has an incentive to mimic one having a good signal. For $p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right)$ and $p_b \pi^M < I < p_g \pi^M$, venture capitalists would not have an incentive to send a false signal.

These results can be summarized graphically similarly to case (i). Figure 9 below shows in the dark grey area the interval of the investment costs for which the truthtelling incentive compatibility constraint is violated.

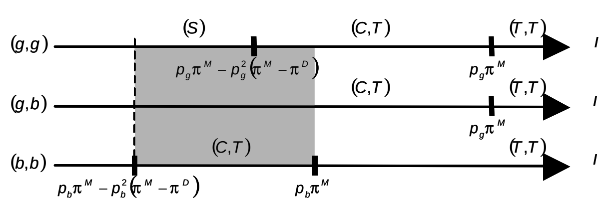

Figure 9: Case (ii): $p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < p_b \pi^M$

In order to show how these results have been obtained, we need to repeat a similar reasoning to the one used in case (i). In practice, it is necessary to check for all possible unilateral incentives to deviate from truthfully revealing the nature of the signal received, as a function of the payoffs which can be obtained for any combination of the signals and taking into consideration which equilibrium configurations of the venture are compatible with this subcase of the analysis. Appendix B shows those intermediate steps for this type of checking for this and the remaining cases.

Case (iii) Remember that in this case assumption 4, $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$, holds, i.e. $\frac{p_g^2}{p_g - p_b} < \frac{\pi^M}{\pi^M - \pi^D} < (p_g + p_b) + \frac{p_g^2}{p_g - p_b}$.

It can be shown that for $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$, a venture capitalist with a bad signal has an incentive to mimic one having a good signal. For $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$, a venture capitalist with a bad signal has an incentive to mimic one having a good signal if and only if $\frac{p_g + p_b}{2}\pi^M - I > 0$. For $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M$, venture capitalists would not have an incentive to send a false signal.

Figure 10 highlights in a dark grey area the interval of the investment costs for which the incentive compatibility constraint for venture capitalists to send true messages is violated when in case (iii).

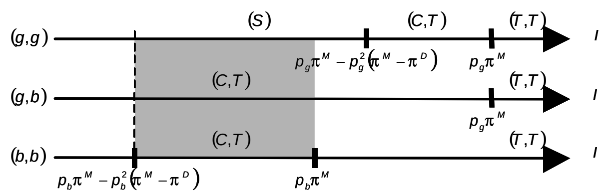

Figure 10: Case (iii): $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$

Appendix B shows the intermediate steps for checking that those incentives are indeed violated for the interval of the investment costs as indicated above.

Case (iv) Remember that in this case assumption 5, $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$, holds, i.e. $(p_g + p_b) + \frac{p_g^2}{p_g - p_b} < \frac{\pi^M}{\pi^M - \pi^D} < \frac{2p_g^2}{p_g - p_b}$.

It can be shown that for $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$, a venture capitalist with a bad signal has an incentive to mimic one with a good signal. For $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$ and $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$, a venture capitalist with a bad signal has an incentive to mimic one with a good signal. For $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$, a venture capitalist with a bad signal has an incentive to mimic one having a good signal if and only if $\frac{p_g + p_b}{2}\pi^M - I > 0$. This condition holds here as $\frac{p_g + p_b}{2}\pi^M > p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) \Leftrightarrow \frac{\pi^M}{\pi^M - \pi^D} < \frac{2p_g^2}{p_g - p_b}$, which is one of the conditions for case (iv) to exist. For $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ and $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M$, venture capitalists would not have an incentive to send a false signal.

Figure 11 shows in the dark and light grey areas the intervals of the investment costs for which the incentive compatibility constraints for venture capitalists to send true messages are violated.

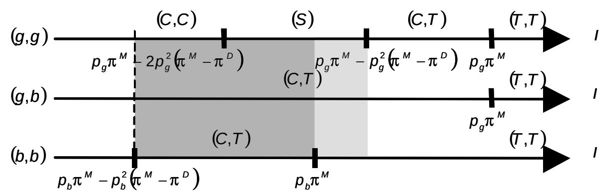

Figure 11: Case (iv): $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$

Appendix B shows once more the intermediate steps for checking that those incentives are indeed violated for the intervals of the investment costs as just described.

Case (v) Remember that in this case assumption 6, $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$, holds, i.e. $\frac{2p_g^2}{p_g - p_b} < \frac{\pi^M}{\pi^M - \pi^D}$.

It can be shown that for $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$, a venture capitalist with a bad signal has an incentive to mimic one with a good signal. For $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$ and $p_b\pi^M < I < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$, venture capitalists would not have an incentive to send a false signal. For $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$ and $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$, a venture capitalist with a bad signal has an incentive to mimic one having a good signal if and only if $\frac{p_g+p_b}{2}\pi^M - I > 0$. This condition holds as $\frac{p_g+p_b}{2}\pi^M > p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) \Leftrightarrow \frac{\pi^M}{\pi^M - \pi^D} < \frac{2p_g^2}{p_g - p_b}$, which is one of the conditions for case (v) to exist. Finally, for $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$ and $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M$, venture capitalists would not have an incentive to send a false signal.

Figure 12 summarizes these results, showing that in both dark and light grey areas the incentive compatibility constraints for venture capitalists to send true messages are violated.

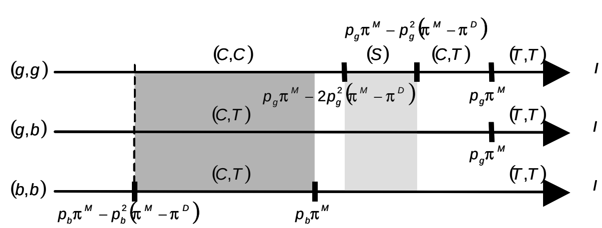

Figure 12: Case (v): $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$

Appendix B gives the intermediate steps for checking that those incentives are indeed violated for those intervals.

All these intermediate results can be summarized as follows.

Proposition 2 *For any $p \in [0,1]$, $a \in \left[\frac{1}{2}, 1\right[$, if $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$, venture capitalists have an incentive to lie - sending untruthful messages - about having received bad signals. In addition, for $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$, venture capitalists with a bad signal have an incentive to lie. Given the incentive to lie when signals are bad, no message, neither good nor bad, is credible for these intervals. For all other cases, there exists instead an equilibrium that implements the full information outcome using truthful messages between venture capitalists.*

Let us label the intervals for which the incentive compatibility constraints are violated as:

$$p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M \qquad \text{(IC-Violation \#1)}$$

and as

$$\max\left\{p_b\pi^M, p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)\right\} < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right). \qquad \text{(IC-Violation \#2)}$$

Note that we define (IC-Violation #2) such that it holds for larger investment levels than (IC-Violation#1), i.e., only in cases (*iv*) and (*v*).

4.2 Symmetric PBE

We have shown that venture capitalists have incentives to misreport the signals as long as the investment costs fall in one of the intervals as just indicated. In these cases, messages are not credible the full information equilibrium outcome cannot be implemented. In this case, we resort to PBE as the solution concept.

A typical strategy for each player assigns for each signal a venture capitalist may have received (1) a recommendation on whether to syndicate (Yes) or not (No), and (2) if syndication was not agreed upon, for each syndication decision of the other venture capitalist, a recommendation about whether to continue investing into the idea (Stay), or to drop out instead (Drop).

For tractability, and given the symmetric nature of the model, we will restrict our attention to candidates for symmetric equilibria only. There are two possible types of equilibria, pooling equilibria, where venture capitalists choose the same syndication decision regardless of their signal, and separating equilibria, where venture capitalists choose different syndication decisions depending on their signal.

4.2.1 Separating equilibria

As in separating equilibria, venture capitalists send different syndication proposals depending on their signal, their counterpart could in equilibrium truthfully infer the other one's signal and take the optimal syndication decision. Given that we restrict our attention to investment levels for which truthful revelation of a venture capitalist's signal is not incentive compatible, the incentive compatibility constraints for separating equilibria cannot be fulfilled either. Thus, for the investment levels for which truthful implementation of the full information equilibrium through messages is not possible, there also does not exist a symmetric separating PBE.

4.2.2 Pooling equilibria

Let us now restrict attention to possible symmetric pooling equilibria. In these equilibria, venture capitalists choose the same syndication decision regardless of their signal.

Subgame after syndication decision node Let us first consider in the subgame that follows no syndication.

Equilibrium candidate 1: ((Stay, Drop), (Stay, Drop)) Consider the equilibrium candidate ((Stay, Drop), (Stay, Drop)). The syndication proposal decision does not convey information on the signal received, thus the probability that the other venture capitalist received a good signal is σ_g and the probability that he received a bad signal is σ_b. Staying after having gotten a good signal gives an expected payoff of

$$\sigma_g \left(p_g^2 \pi^D + p_g \left(1 - p_g\right) \pi^M\right) + \sigma_b p_g \pi^M - I,$$

whereas dropping out gives zero. Staying after having received a bad signal gives an expected payoff of

$$\sigma_g \left(p_b p_g \pi^D + p_b \left(1 - p_g\right) \pi^M\right) + \sigma_b p_b \pi^M - I,$$

wherease dropping out gives zero again. After simplification, it is possible to show that, in this subgame, ((Stay, Drop), (Stay, Drop)) is an equilibrium if

$$p_b \pi^M - \sigma_g p_g p_b \left(\pi^M - \pi^D\right) < I < p_g \pi^M - \sigma_g p_g^2 \left(\pi^M - \pi^D\right).$$

As $p_b \pi^M - \sigma_g p_g p_b \left(\pi^M - \pi^D\right) < p_g \pi^M - \sigma_g p_g^2 \left(\pi^M - \pi^D\right)$, there are always I such that this equilibrium exists.

Equilibrium candidate 2: ((Drop, Stay), (Drop, Stay)) Consider the equilibrium candidate ((Drop, Stay), (Drop, Stay)). The syndication proposal decision does not convey information on the signal received, thus the probability that the other venture capitalist received a good signal is σ_g and the probability that he received a bad signal is σ_b. Staying after having gotten a good signal gives an expected payoff of

$$\sigma_g p_g \pi^M + \sigma_b \left(p_g p_b \pi^D + p_g \left(1 - p_b\right) \pi^M\right) - I$$

whereas dropping out gives zero. Staying after having received a bad signal gives an expected payoff of

$$\sigma_g p_b \pi^M + \sigma_b \left(p_b^2 \pi^D + p_b \left(1 - p_b\right) \pi^M\right) - I,$$

wherease dropping out gives zero again. To drop after a good signal and stay after a bad signal, we would need

$$\sigma_g p_g \pi^M + \sigma_b \left(p_g p_b \pi^D + p_g (1-p_b)\pi^M\right) - I < 0$$

and

$$\sigma_g p_b \pi^M + \sigma_b \left(p_b^2 \pi^D + p_b (1-p_b)\pi^M\right) - I > 0,$$

which implies

$$\sigma_b p_b > \frac{\pi^M}{\pi^M - \pi^D}.$$

This is not possible as $\sigma_b p_b \in [0,1]$ and $\frac{\pi^M}{\pi^M - \pi^D} \in [1,2]$.

Equilibrium candidate 3: ((Stay, Stay),(Stay, Stay)) Consider the candidate ((Stay, Stay),(Stay, Stay)). Staying after a good signal gives an expected payoff of

$$\sigma_g \left(p_g^2 \pi^D + p_g (1-p_g)\pi^M\right) + \sigma_b \left(p_g p_b \pi^D + p_g (1-p_b)\pi^M\right) - I,$$

wherease dropping out gives zero. Staying after a bad signal gives an expected payoff of

$$\sigma_g \left(p_b p_g \pi^D + p_b (1-p_g)\pi^M\right) + \sigma_b \left(p_b^2 \pi^D + p_b (1-p_b)\pi^M\right) - I,$$

whereas dropping out gives zero. Both have to be greater than zero for ((Stay, Stay),(Stay, Stay)) to be optimal, which simplifies to

$$\sigma_g \left(p_b p_g \pi^D + p_b (1-p_g)\pi^M\right) + \sigma_b \left(p_b^2 \pi^D + p_b (1-p_b)\pi^M\right) > I,$$

or

$$p_b \pi^M - p_b p \left(\pi^M - \pi^D\right) > I.$$

This violates Assumption 1.

Equilibrium candidate 4: ((Drop, Drop),(Drop, Drop)) Consider the candidate ((Drop, Drop),(Drop, Drop)). Staying after a good signal gives an expected payoff of

$$p_g \pi^M - I,$$

wherease dropping out gives zero. Staying after a bad signal gives an expected payoff of

$$p_b \pi^M - I,$$

whereas dropping out gives zero. For dropping out to be optimal, it must be that both are negative, which violates Assumption 1.

Summary 1 *The only symmetric Bayesian equilibrium in the stage after the syndication decision is ((Stay, Drop), (Stay, Drop)).*

We now examine whether this equilibrium exists in the I intervals for which the incentive compatibility constraints for truthtelling are violated. For that, define as

$$\begin{aligned} \underline{I}^{IC1} &: = p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right), \text{ and} \\ \overline{I}^{IC1} &: = p_b \pi^M \end{aligned}$$

the lower and upper bound of (IC-Violation #1) if it holds, and as

$$\begin{aligned} \underline{I}^{IC2} &: = \max\left\{p_b \pi^M, p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right)\right\}, \text{ and} \\ \overline{I}^{IC2} &: = p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right), \end{aligned}$$

the lower and upper bound of (IC-Violation #2) if it holds for larger investment levels than (IC-Violation #1). Furthermore, define as

$$\begin{aligned} \underline{I}^{SD} &: = p_b \pi^M - \sigma_g p_g p_b \left(\pi^M - \pi^D\right), \text{ and} \\ \overline{I}^{SD} &: = p_g \pi^M - \sigma_g p_g^2 \left(\pi^M - \pi^D\right) \end{aligned}$$

the lower and upper bound of investment levels for which ((Stay, Drop), (Stay, Drop)) exists in the stage after the syndication decision.

First note that, as $\underline{I}^{SD} < \underline{I}^{IC2}$ and $\overline{I}^{SD} > \overline{I}^{IC2}$, ((Stay, Drop), (Stay, Drop)) exists in (IC-Violation #2). Second, note that $\underline{I}^{SD} < \overline{I}^{IC1}$, but $\underline{I}^{SD} \lesseqgtr \underline{I}^{IC1}$, $\overline{I}^{SD} \lesseqgtr \underline{I}^{IC1}$, and $\overline{I}^{SD} \lesseqgtr \overline{I}^{IC1}$. This gives the following result.

Lemma 1 *1. ((Stay, Drop), (Stay, Drop)) exists in the stage after the syndication decision $\forall I \in$(IC-Violation #2).*

2. ((Stay, Drop), (Stay, Drop)) exists in the stage after the syndication decision

(a) $\forall I \in \left[\underline{I}^{IC1}, \overline{I}^{IC1}\right]$ if $\underline{I}^{SD} < \underline{I}^{IC1} < \overline{I}^{IC1} < \overline{I}^{SD}$, i.e., for all investment levels in (IC-Violation #1),

(b) $\forall I \in \left[\underline{I}^{IC1}, \overline{I}^{SD}\right]$ if $\underline{I}^{SD} < \underline{I}^{IC1} < \overline{I}^{SD} < \overline{I}^{IC1}$, i.e., for low investment levels in (IC-Violation #1),

(c) $\forall I \in \left[\underline{I}^{SD}, \overline{I}^{SD}\right]$ if $\underline{I}^{IC1} < \underline{I}^{SD} < \overline{I}^{SD} < \overline{I}^{IC1}$, i.e., for intermediate investment levels in (IC-Violation #1),

(d) $\forall I \in \left[\underline{I}^{SD}, \overline{I}^{IC1}\right]$ if $\underline{I}^{IC1} < \underline{I}^{SD} < \overline{I}^{IC1} < \overline{I}^{SD}$, i.e., for high investment levels in (IC-Violation #1), and

(e) for no investment levels in (IC-Violation #1) if $\underline{I}^{SD} < \overline{I}^{SD} < \underline{I}^{IC1} < \overline{I}^{SD} < \overline{I}^{IC1}$.

Figure 13 gives a graphical intuition for part 2 of Lemma 1. In region (a), ((Stay, Drop), (Stay, Drop)) exists on the whole interval in which the incentive compatibility constraint is violated. In region (b), it exists for low investment levels, in region (c) for intermediate investment levels, in region (d) for high investment levels, and in region (e) it does not exist in the interval in question.

The equilibrium ((Stay, Drop), (Stay, Drop)) always exists for some investment levels in (IC-Violation #1), except for a combination of a very high ex ante probability of success, very accurate signals, and very strong competition. Furthermore note that, as $p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < \overline{I}^{SD}$, region (e) only exists for parameter constellations in which, with public signals, syndication would not occur.

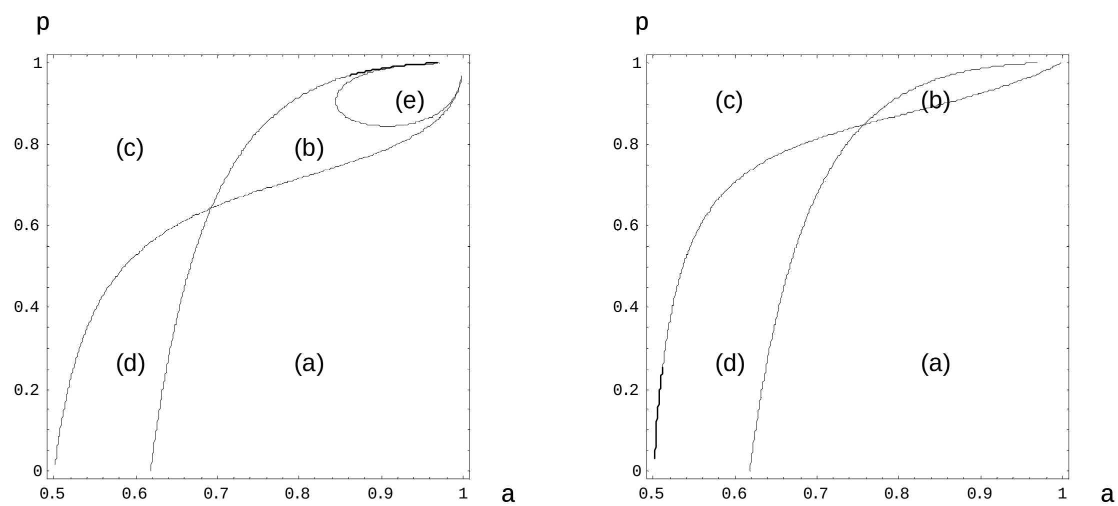

Figure 13: Existence of ((Stay, Drop), (Stay, Drop)) for strong competition (left panel) and for lax competition (right panel).

Syndication Decision – Pooling on Syndication If a venture capitalist received a good signal, syndication gives an expected payoff of

$$\frac{1}{2}\sigma_g \left(p_g \pi^M - I\right) + \frac{1}{2}\sigma_b \left(\frac{p_b + p_g}{2}\pi^M - I\right),$$

and if he received a bad signal, syndication give an expected payoff of

$$\frac{1}{2}\sigma_g \left(\frac{p_g + p_b}{2}\pi^M - I\right) + \frac{1}{2}\sigma_b \left(p_b \pi^M - I\right).$$

Consider the only symmetric Bayesian equilibrium candidate ((*Stay, Drop*), (*Stay, Drop*)) in the subgame following the syndication announcements. Agreeing on syndication in stage 1 is profitable for a venture capitalist with a good signal if

$$\frac{1}{2}\sigma_g\left(p_g\pi^M - I\right) + \frac{1}{2}\sigma_b\left(\frac{p_b + p_g}{2}\pi^M - I\right) > \sigma_g\left(p_g^2\pi^D + p_g\left(1 - p_g\right)\pi^M\right) + \sigma_b p_g \pi^M - I,$$

or

$$I > \left(2p_g - \sigma_g p_g - \sigma_b\frac{p_b + p_g}{2}\right)\pi^M - 2\sigma_g p_g^2\left(\pi^M - \pi^D\right),$$

and for a venture capitalist with a bad signal if

$$\frac{1}{2}\sigma_g\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \frac{1}{2}\sigma_b\left(p_b\pi^M - I\right) > 0$$

or

$$\sigma_g\frac{p_g + p_b}{2}\pi^M + \sigma_b p_b \pi^M > I.$$

These two conditions can only hold if

$$\left(2p_g - \sigma_g p_g - \sigma_b\frac{p_b + p_g}{2}\right)\pi^M - 2\sigma_g p_g^2\left(\pi^M - \pi^D\right) < \sigma_g\frac{p_g + p_b}{2}\pi^M + \sigma_b p_b \pi^M,$$

which reduces to

$$\frac{\pi^M}{\pi^M - \pi^D} < \frac{2\sigma_g p_g^2}{2p_g - p - \frac{p_g + p_b}{2}}.$$

Syndication Decision – Pooling on No Syndication If a venture capitalist received a good signal, syndication gives an expected payoff of

$$\frac{1}{2}\sigma_g\left(p_g\pi^M - I\right) + \frac{1}{2}\sigma_b\left(\frac{p_b + p_g}{2}\pi^M - I\right),$$

and if he received a bad signal, syndication give an expected payoff of

$$\frac{1}{2}\sigma_g\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \frac{1}{2}\sigma_b\left(p_b\pi^M - I\right).$$

Consider again the only symmetric equilibrium candidate, ((*Stay, Drop*), (*Stay, Drop*)) in the subgame following the syndication announcements. Not agreeing on syndication in stage 1 is profitable for a venture capitalist with a good signal if

$$\frac{1}{2}\sigma_g\left(p_g\pi^M - I\right) + \frac{1}{2}\sigma_b\left(\frac{p_b + p_g}{2}\pi^M - I\right) < \sigma_g\left(p_g^2\pi^D + p_g\left(1 - p_g\right)\pi^M\right) + \sigma_b p_g \pi^M - I,$$

or

$$I < \left(2p_g - \sigma_g p_g - \sigma_b\frac{p_b + p_g}{2}\right)\pi^M - 2\sigma_g p_g^2\left(\pi^M - \pi^D\right),$$

and for a venture capitalist with a bad signal if

$$\frac{1}{2}\sigma_g\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \frac{1}{2}\sigma_b\left(p_b\pi^M - I\right) < 0$$

or

$$\sigma_g \frac{p_g + p_b}{2} \pi^M + \sigma_b p_b \pi^M < I.$$

These two conditions can only hold if

$$\left(2p_g - \sigma_g p_g - \sigma_b \frac{p_b + p_g}{2}\right) \pi^M - 2\sigma_g p_g^2 \left(\pi^M - \pi^D\right) > \sigma_g \frac{p_g + p_b}{2} \pi^M + \sigma_b p_b \pi^M,$$

which reduces to

$$\frac{\pi^M}{\pi^M - \pi^D} > \frac{2\sigma_g p_g^2}{2p_g - p - \frac{p_g + p_b}{2}}.$$

This is the opposite condition to the condition for pooling on Syndication.

In figure 14, we illustrate the VCs' syndication decision in the symmetric PBEs. If the two symmetric PBEs exist, VCs syndicate for $a - p-$combinations above the dashed line. They do not syndicate, and each VC continues alone if he received a good signal and terminates his project if he received a bad signal below the dashed line. These PBEs always exist in (IC-Violation #2). They exist for all investment levels in (IC-Violation #1) in region (a), for low investment levels in (IC-Violation #1) in region (b), for intermediate investment levels in (IC-Violation #1) in region (c), for high investment levels in (IC-Violation #1) in region (d), and for no investment levels in (IC-Violation #1) in region (e). Regions (a) - (e) are separated by solid lines.

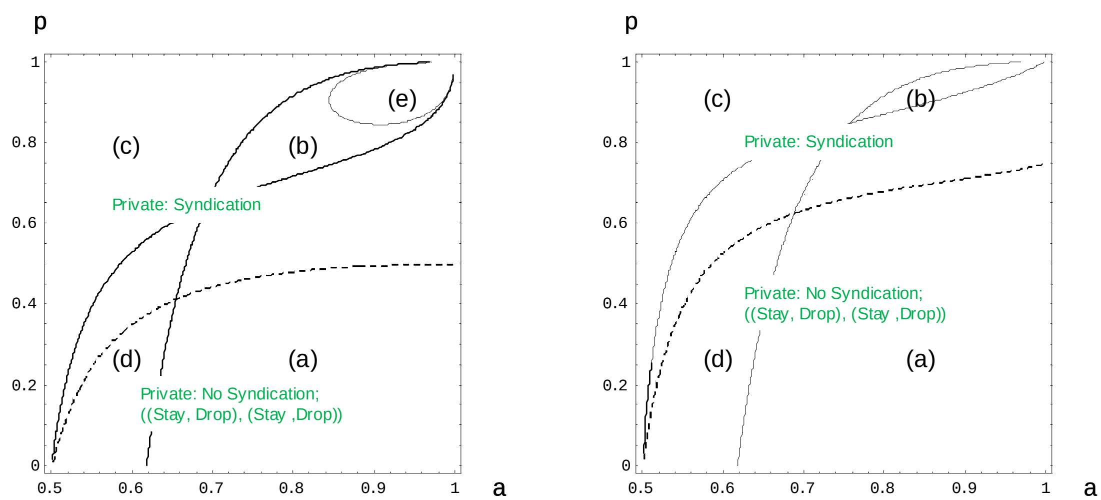

Figure 14: Symmetric PBEs for strong competition (left panel) and lax competition (right panel)

4.3 Results

In figure 15, we compare the VCs syndication choice with public and private signals. Separated by solid lines, we have the possible equilibria for public signals and separated by the dashed line the possible symmetric PBEs for private signals. As the graphs illustrate, in the symmetric PBE, there will be pooling on syndication only for parameter constellations for which, with public signals, there was either syndication (S) or continuation of only one project (C,T), but not for parameter constellations for which the VCs would have continued both. As the graphs also show, in the symmetric PBE, there will be pooling on no syndication for parameter constellations for which there would have been syndication before.

Finally, as shown above, in the no syndication pooling equilibrium, if both VCs get a bad signal, they both drop out. In (IC-Violation #1), one of them would have continued with public signals.

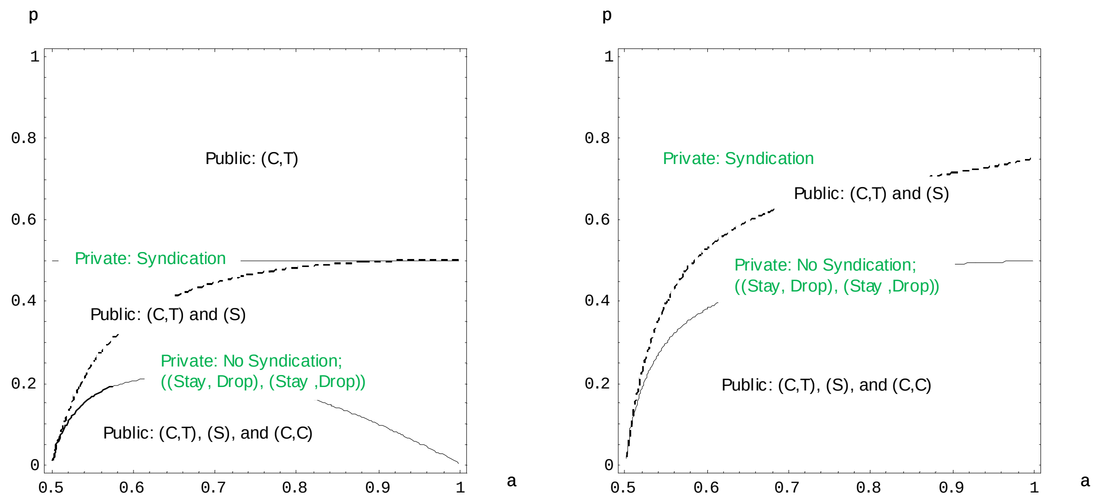

Figure 15: Comparison of public signals equilibria and symmetric PBEs for strong competition (left panel) and lax competition (right panel)

These results can be summarized in the following proposition.

Proposition 3 *With private signals, in the symmetric PBEs, (1) venture capitalists do not syndicate in cases where they would have competed with public signals; (2) they do, however, compete in cases where they would have syndicated or continued alone with public signals; and, (3) in the symmetric PBE without syndication, both venture capitalists drop out if both receive a bad signal, whereas one of them would have continued alone with public signals.*

4.4 Welfare implications

Even though there will still be syndication, and therefore termination, of good projects in order to reduce competition in the market place, with private signals this will happen to a lesser extent than with public signals. Therefore, the detrimental effect of syndication for social welfare is reduced: when venture capitalists cannot send credible messages about the nature of their signals, competition may replace syndication. This is true also for parameter constellations for which, under public signals, VCs choose welfare-reducing syndication over competing venture-backed firms.

5 Conclusion

In this paper, we have provided an alternative rationale for syndication to occur, than the ones proposed so far by the existing literature on venture capital. In our model, syndication is associated with the elimination of viable projects, when the innovations they would lead to would be rival in the final markets otherwise.

We have analyzed the incentives to syndicate both for the cases of public and private signals acquired by the venture capitalists prior to their investment decisions. Under public signals, our results confirm that venture capitalists have incentives to syndicate, i.e. to eliminate the potentially competing ideas, when they received good signals, and the level of the investment required to develop the ideas is not too high. Thus, syndication is detrimental to social welfare, as competition would have been otherwise viable whenever syndication is instead chosen. Under private signals, this detrimental effect for social welfare is reduced: when venture capitalists cannot send credible messages about the nature of their signals, competition may replace syndication. An additional effect has been obtained, which is welfare decreasing instead. Under private signals, if venture capitalists both receive bad signals, they happen to abandon their ideas while one of them would have continued it under the public signals environment.

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Appendix

A Properties of the equilibrium configurations of ventures for the public signals case

Case (i)

Lemma 2 *In equilibrium, if* $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$ *and*

1. $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$*, then only one project is continued by one of the VCs alone, irrespective of the combination of the signals received by the VCs;*

2. $p_b\pi^M < I < p_g\pi^M$*, then only one project is continued (i) by either of the VCs if both received a good signal, or (ii) by the only VC who received a good signal. Both projects are terminated otherwise.*

Case (ii)

Lemma 3 *In equilibrium, if* $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M$ *and*

1. $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$*, only one project is continued (i) by syndication if both VCs received a good signal, or (ii) by one VC alone otherwise;*

2. $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$*, only one project is continued by one of the VCs alone, irrespective of the combination of the signals received by the VCs;*

3. $p_b\pi^M < I < p_g\pi^M$*, only one project is continued (i) by either of the VCs if both received a good signal, or (ii) by the only VC who received a good signal. Both projects are terminated otherwise.*

Case (iii)

Lemma 4 *In equilibrium, if* $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right)$, $p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$, *and*

1. $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$*, only one project is continued (i) by syndication if both VCs received a good signal, (ii) by the only VC who received a good signal, or (iii) by either of the VCs otherwise;*

2. $p_b\pi^M < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$*, only one project is continued (i) by syndication if both VCs received a good signal, or (ii) by the only VC who received a good signal. Both projects are terminated otherwise;*

3. $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M$*, only one project is continued (i) by either of the VCs if both received a good signal, or (ii) by the only VC who received a good signal. Both projects are terminated otherwise.*

Case (iv)

Lemma 5 *In equilibrium, if* $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < p_b\pi^M < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$ *and*

1. $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$*, both projects are continued if both VCs receive a good signal. Only one project is continued (i) by the only VC who received a good signal, or (ii) by either of the VCs who received a bad signal;*

2. $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$*, only one project is continued (i) by syndication if both VCs received a good signal, (ii) by the only VC who received a good signal, or (iii) by either of the VCs otherwise;*

3. $p_b\pi^M < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$*, only one project is continued (i) by syndication if both VCs received a good signal, or (ii) by the only VC who received a good signal. Both projects are terminated otherwise;*

4. $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M$*, only one project is continued (i) by either of the VCs who received a good signal, or (ii) by the only VC who received a good signal. Both projects are terminated otherwise.*

Case (v)

Lemma 6 *In equilibrium, if* $p_b\pi^M < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$ *and*

1. $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$*, both projects are continued if both VCs receive a good signal. Only one project is continued (i) by the only VC who received a good signal, or (ii) by either of the VCs who received a bad signal;*

2. $p_b\pi^M < I < p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right)$*, both projects are continued if both VCs receive a good signal. Only one project is continued by the only VC who received a good signal. Both projects are terminated otherwise.*

3. $p_g\pi^M - 2p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$*, only one project is continued (i) by syndication if both VCs received a good signal, or (ii) by the only VC who received a good signal. Both projects are terminated otherwise;*

4. $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M$*, only one project is continued (i) by either of the VCs who received a good signal; or (ii) by the only VC who received a good signal; and both projects are terminated otherwise.*

B Checking of the Incentive Compatibility constraints (ICs) for the private signals case

Case (ii)

- Assume first $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$
  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right)$$

* If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g (1 - p_g) \pi^M - I\right) + \sigma_b \left(\frac{1}{2}\left(p_g p_b \pi^D + p_g (1 - p_b) \pi^M - I\right) + \frac{1}{2}\left(p_g \pi^M - I\right)\right)$$

* If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \frac{1}{2}\left(p_b \pi^M - I\right)$$

* If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \sigma_b \left(p_b \pi^M - I\right)$$

- Assume now $p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < I < p_b \pi^M$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \frac{1}{2}\left(p_g \pi^M - I\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \frac{1}{2}\left(p_b \pi^M - I\right)$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_b \pi^M - I\right) + \sigma_b \left(p_b \pi^M - I\right)$$

- Assume now $p_b \pi^M < I < p_g \pi^M$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

Case *(iii)*

- Assume first $p_b\pi^M - p_b^2\left(\pi^M - \pi^D\right) < I < p_b\pi^M$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g\left(p_g^2\pi^D + p_g\left(1-p_g\right)\pi^M - I\right) + \sigma_b\left(\frac{1}{2}\left(p_g p_b\pi^D + p_g\left(1-p_b\right)\pi^M - I\right) + \frac{1}{2}\left(p_g\pi^M - I\right)\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot \frac{1}{2}\left(p_b\pi^M - I\right)$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot \frac{1}{2}\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \sigma_b \cdot \left(p_b\pi^M - I\right)$$

- Assume now $p_b\pi^M < I < p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right)$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g\left(p_g^2\pi^D + p_g\left(1-p_g\right)\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \sigma_b \cdot 0$$

- Assume now $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right)$$

* If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \left(p_g \pi^M - I\right)$$

* If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

* If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

Case (iv)

- Assume first $p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < I < p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right)$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g \left(1 - p_g\right) \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g \left(1 - p_g\right) \pi^M - I\right) + \sigma_b \left(\frac{1}{2} \left(p_g p_b \pi^D + p_g \left(1 - p_b\right) \pi^M - I\right) + \frac{1}{2} \left(p_g \pi^M - I\right)\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot \frac{1}{2} \left(p_b \pi^M - I\right)$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot \left(p_b \pi^M - I\right)$$

- Assume now $p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right) < I < p_b \pi^M$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2} \left(p_g \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g \left(1 - p_g\right) \pi^M - I\right) + \sigma_b \left(\frac{1}{2} \left(p_g p_b \pi^D + p_g \left(1 - p_b\right) \pi^M - I\right) + \frac{1}{2} \left(p_g \pi^M - I\right)\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot \frac{1}{2} \left(p_b \pi^M - I\right)$$

* If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot \frac{1}{2}\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \sigma_b \cdot \left(p_b \pi^M - I\right)$$

- Assume now $p_b \pi^M < I < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right)$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g \left(1 - p_g\right) \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \sigma_b \cdot 0$$

- Assume now $p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right) < I < p_g \pi^M$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

Case (v)

- Assume first $p_b \pi^M - p_b^2 \left(\pi^M - \pi^D\right) < I < p_b \pi^M$

- * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g (1 - p_g) \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

  * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g (1 - p_g) \pi^M - I\right) + \sigma_b \left(\frac{1}{2} \left(p_g p_b \pi^D + p_g (1 - p_b) \pi^M - I\right) + \frac{1}{2} \left(p_g \pi^M - I\right)\right)$$

  * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot \frac{1}{2} \left(p_b \pi^M - I\right)$$

  * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot \left(p_b \pi^M - I\right)$$

- Assume now $p_b \pi^M < I < p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right)$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g (1 - p_g) \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g (1 - p_g) \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

- Assume now $p_g \pi^M - 2p_g^2 \left(\pi^M - \pi^D\right) < I < p_g \pi^M - p_g^2 \left(\pi^M - \pi^D\right)$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2} \left(p_g \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \left(p_g^2 \pi^D + p_g (1 - p_g) \pi^M - I\right) + \sigma_b \left(p_g \pi^M - I\right)$$

- * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

  * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot \frac{1}{2}\left(\frac{p_g + p_b}{2}\pi^M - I\right) + \sigma_b \cdot 0$$

- Assume now $p_g\pi^M - p_g^2\left(\pi^M - \pi^D\right) < I < p_g\pi^M$

  - * If $s_1 = g$ and $m_1 = g$, then VC_1 gets

$$\sigma_g \frac{1}{2}\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right)$$

    * If $s_1 = g$, but $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b\left(p_g\pi^M - I\right)$$

    * If $s_1 = b$ and $m_1 = b$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

    * If $s_1 = b$, but $m_1 = g$, then VC_1 gets

$$\sigma_g \cdot 0 + \sigma_b \cdot 0$$

C Bayesian equilibria in the Drop/Stay subgame in Pooling

C.1 Good signal

Suppose VC1 received a good signal, $s_1 = g$. Then we need to compute his best response for every strategy VC2 can choose.

Suppose VC2 chooses (Stay if $s_2 = g$, Stay if $s_2 = b$). Then

$$\begin{aligned} E\Pi_1(Stay) &= \sigma_g\left(p_g^2\pi^D + p_g(1-p_g)\pi^M - I\right) + \sigma_b\left(p_g p_b\pi^D + p_g(1-p_b)\pi^M - I\right), \\ E\Pi_1(Drop) &= 0. \end{aligned}$$

Suppose VC2 chooses (Stay if $s_2 = g$, Drop if $s_2 = b$). Then

$$\begin{aligned} E\Pi_1(Stay) &= \sigma_g\left(p_g^2\pi^D + p_g(1-p_g)\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right), \\ E\Pi_1(Drop) &= 0. \end{aligned}$$

Suppose VC2 chooses (Drop if $s_2 = g$, Stay if $s_2 = b$). Then

$$\begin{aligned} E\Pi_1(Stay) &= \sigma_g\left(p_g\pi^M - I\right) + \sigma_b\left(p_g p_b\pi^D + p_g(1-p_b)\pi^M - I\right), \\ E\Pi_1(Drop) &= 0. \end{aligned}$$

Suppose VC2 chooses (Drop if $s_2 = g$, Drop if $s_2 = b$). Then

$$\begin{aligned} E\Pi_1(Stay) &= \sigma_g\left(p_g\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right), \\ E\Pi_1(Drop) &= 0. \end{aligned}$$

C.2 Bad signal

Suppose VC1 received a bad signal, $s_1 = b$. Then we need to compute his best response for every strategy VC2 can choose.

Suppose VC2 chooses (Stay if $s_2 = g$, Stay if $s_2 = b$). Then

$$\begin{aligned} E\Pi_1(Stay) &= \sigma_g\left(p_b p_g\pi^D + p_b(1-p_g)\pi^M - I\right) + \sigma_b\left(p_b^2\pi^D + p_b(1-p_b)\pi^M - I\right), \\ E\Pi_1(Drop) &= 0. \end{aligned}$$

Suppose VC2 chooses (Stay if $s_2 = g$, Drop if $s_2 = b$). Then

$$\begin{aligned} E\Pi_1(Stay) &= \sigma_g\left(p_b p_g\pi^D + p_b(1-p_g)\pi^M - I\right) + \sigma_b\left(p_b\pi^M - I\right), \\ E\Pi_1(Drop) &= 0. \end{aligned}$$

Suppose VC2 chooses (Drop if $s_2 = g$, Stay if $s_2 = b$). Then

$$\begin{aligned} E\Pi_1(Stay) &= \sigma_g\left(p_b\pi^M - I\right) + \sigma_b\left(p_b^2\pi^D + p_b(1-p_b)\pi^M - I\right), \\ E\Pi_1(Drop) &= 0. \end{aligned}$$

Suppose VC2 chooses (Drop if $s_2 = g$, Drop if $s_2 = b$). Then

$$\begin{aligned} E\Pi_1(Stay) &= \sigma_g\left(p_b\pi^M - I\right) + \sigma_b\left(p_b\pi^M - I\right), \\ E\Pi_1(Drop) &= 0. \end{aligned}$$

C.3 Best responses

- Best response to (Stay, Stay)
  - Stay if good as long as

$$\begin{aligned} \sigma_g\left(p_g^2\pi^D + p_g(1-p_g)\pi^M - I\right) + \sigma_b\left(p_g p_b\pi^D + p_g(1-p_b)\pi^M - I\right) &> 0 \\ \sigma_g p_g^2\pi^D + \sigma_g p_g(1-p_g)\pi^M + \sigma_b p_g p_b\pi^D + \sigma_b p_g(1-p_b)\pi^M &> I \\ \sigma_g p_g^2\pi^D + \sigma_g p_g\pi^M - \sigma_g p_g^2\pi^M + \sigma_b p_g p_b\pi^D + \sigma_b p_g\pi^M - \sigma_b p_g p_b\pi^M &> I \\ p_g\pi^M - \sigma_g p_g^2\left(\pi^M - \pi^D\right) - \sigma_b p_g p_b\left(\pi^M - \pi^D\right) &> I \\ p_g\pi^M - \left(\sigma_g p_g^2 + \sigma_b p_g p_b\right)\left(\pi^M - \pi^D\right) &> I \\ p_g\pi^M - p_g p\left(\pi^M - \pi^D\right) &> I \qquad (1) \end{aligned}$$

– Stay if bad as long as

$$\begin{aligned}
\sigma_g\left(p_b p_g \pi^D + p_b\left(1-p_g\right)\pi^M - I\right) + \sigma_b\left(p_b^2\pi^D + p_b\left(1-p_b\right)\pi^M - I\right) &> 0 \\
\sigma_g p_b p_g \pi^D + \sigma_g p_b\left(1-p_g\right)\pi^M + \sigma_b p_b^2 \pi^D + \sigma_b p_b\left(1-p_b\right)\pi^M &> I \\
\sigma_g p_b p_g \pi^D + \sigma_g p_b \pi^M - \sigma_g p_b p_g \pi^M + \sigma_b p_b^2 \pi^D + \sigma_b p_b \pi^M - \sigma_b p_b^2 \pi^M &> I \\
p_b \pi^M - \sigma_g p_b p_g\left(\pi^M - \pi^D\right) - \sigma_b p_b^2\left(\pi^M - \pi^D\right) &> I \\
p_b \pi^M - \left(\sigma_g p_b p_g + \sigma_b p_b^2\right)\left(\pi^M - \pi^D\right) &> I \\
p_b \pi^M - p_b p\left(\pi^M - \pi^D\right) &> I \qquad (2)
\end{aligned}$$

– (Stay, Stay) would be a best response to (Stay, Stay) if both inequalities hold, which boils down to (2) holding. This is not possible.

– Therefore, (Stay, Stay) is not a best response to (Stay, Stay) in the relevant intervals

- Best response to (Stay, Drop)

– Stay if good as long as

$$\begin{aligned}
\sigma_g\left(p_g^2\pi^D + p_g\left(1-p_g\right)\pi^M - I\right) + \sigma_b\left(p_g\pi^M - I\right) &> 0 \\
\sigma_g p_g^2 \pi^D + \sigma_g p_g\left(1-p_g\right)\pi^M + \sigma_b p_g \pi^M &> I \\
\sigma_g p_g^2 \pi^D + \sigma_g p_g \pi^M - \sigma_g p_g^2 \pi^M + \sigma_b p_g \pi^M &> I \\
p_g \pi^M - \sigma_g p_g^2\left(\pi^M - \pi^D\right) &> I \qquad (3)
\end{aligned}$$

– Stay if bad as long as

$$\begin{aligned}
\sigma_g\left(p_b p_g \pi^D + p_b\left(1-p_g\right)\pi^M - I\right) + \sigma_b\left(p_b\pi^M - I\right) &> 0 \\
\sigma_g p_b p_g \pi^D + \sigma_g p_b\left(1-p_g\right)\pi^M + \sigma_b p_b \pi^M &> I \\
\sigma_g p_b p_g \pi^D + \sigma_g p_b \pi^M - \sigma_g p_b p_g \pi^M + \sigma_b p_b \pi^M &> I \\
p_b \pi^M - \sigma_g p_b p_g\left(\pi^M - \pi^D\right) &> I \qquad (4)
\end{aligned}$$

– (Stay, Drop) would be a best response to (Stay, Drop) if

$$\begin{aligned}
p_g \pi^M - \sigma_g p_g^2\left(\pi^M - \pi^D\right) &> I \\
p_b \pi^M - \sigma_g p_b p_g\left(\pi^M - \pi^D\right) &< I,
\end{aligned}$$

which is possible as long as

$$\sigma_g p_g < \frac{\pi^M}{\pi^M - \pi^D}$$

- Best response to (Drop, Stay)
  - Stay if good as long as

$$\begin{aligned}
\sigma_g\left(p_g\pi^M - I\right) + \sigma_b\left(p_g p_b \pi^D + p_g\left(1-p_b\right)\pi^M - I\right) &> 0 \\
\sigma_g p_g \pi^M + \sigma_b p_g p_b \pi^D + \sigma_b p_g\left(1-p_b\right)\pi^M &> I \\
\sigma_g p_g \pi^M + \sigma_b p_g p_b \pi^D + \sigma_b p_g \pi^M - \sigma_b p_g p_b \pi^M &> I \\
p_g \pi^M - \sigma_b p_g p_b\left(\pi^M - \pi^D\right) &> I
\end{aligned}$$

  - Stay if bad as long as

$$\begin{aligned}
\sigma_g\left(p_b\pi^M - I\right) + \sigma_b\left(p_b^2 \pi^D + p_b\left(1-p_b\right)\pi^M - I\right) &> 0 \\
\sigma_g p_b \pi^M + \sigma_b p_b^2 \pi^D + \sigma_b p_b\left(1-p_b\right)\pi^M &> I \\
p_b \pi^M - \sigma_b p_b^2\left(\pi^M - \pi^D\right) &> I
\end{aligned}$$

  - (Drop, Stay) would be a best response to (Drop, Stay) if

$$\begin{aligned}
p_g \pi^M - \sigma_b p_g p_b\left(\pi^M - \pi^D\right) &< I \\
p_b \pi^M - \sigma_b p_b^2\left(\pi^M - \pi^D\right) &> I,
\end{aligned}$$

    which would be possible as long as

$$\frac{\pi^M}{\pi^M - \pi^D} < \sigma_b p_b$$

  - As this is not possible, (Drop, Stay) is not a best response to (Drop, Stay)
- Best response to (Drop, Drop)
  - Stay if good as long as

$$\begin{aligned}
p_g \pi^M - I &> 0 \\
p_g \pi^M &> I
\end{aligned}$$

  - Stay if bad as long as

$$\begin{aligned}
p_b \pi^M - I &> 0 \\
p_b \pi^M &> I
\end{aligned}$$

  - (Drop, Drop) is not a best reponse to (Drop, Drop) in the relevant intervals