

# 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 either a selection hypothesis, 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  $\Pr(\text{good}) := p \in ]0, 1[$  and the probability of failure is  $\Pr(\text{bad}) := 1 - p$ . 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 (further) investment, venture capitalist  $i$  receives a signal  $s_i \in \{g, b\}$  from her past involvement in venture  $i$ , where  $g$  stands for a good signal and  $b$  for a bad one.<sup>1</sup>

Signals are assumed to be imperfect and are correct with probability  $a \in [\frac{1}{2}, 1[$ , i.e.,  $a := \Pr(s_i = g | \text{good}) \equiv \Pr(s_i = b | \text{bad})$ . The parameter  $a$  can also be interpreted as the precision of the signal.<sup>2</sup> 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.

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<sup>1</sup>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.

<sup>2</sup>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 assessment - a bad signal in our model - would imply that the idea fails with certainty; while a positive assessment - 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<sup>3</sup> and it is non-verifiable and manipulable.<sup>4</sup> 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  $\sigma_g$ , with  $\sigma_g = ap + (1 - a)(1 - p)$ , and the ex-ante probability of getting a bad signal as  $\sigma_b$ , 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  $p_g := \Pr(\text{good} | s_i = g) = \frac{ap}{\sigma_g}$  and the updated probability of success of a project given that a bad signal has been observed, denoted  $p_b$ , as  $p_b := \Pr(\text{good} | s_i = b) = \frac{(1-a)p}{\sigma_b}$ .

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.<sup>5</sup>

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,  $\pi^D$ . 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,  $\pi^M$ . We assume  $2\pi^D \leq \pi^M$ .<sup>6</sup>

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 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.

<sup>3</sup>With the alternative interpretation, it is revealed only to the venture capitalist who scrutinized the business plan.

<sup>4</sup>Note that whether signals are reliable or not, is not incompatible with signals being either public or private.

<sup>5</sup>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.

<sup>6</sup>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.

**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

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

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

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

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 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:

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

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**  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$ .

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

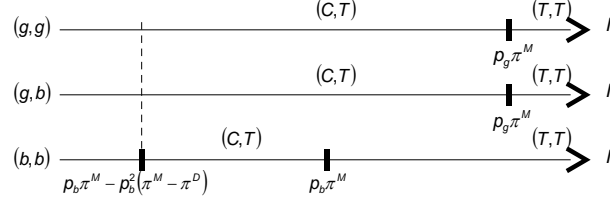


Figure 1. Case (i):  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$

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 1 (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  $\pi^D \in [0, \frac{\pi^M}{2}]$ . For strong competition, i.e., for  $\pi^D = 0$ ,  $\frac{\pi^M}{\pi^M - \pi^D} = 1 < p_g + p_b \Leftrightarrow p > \frac{1}{2}$ ,  $\forall a \in [\frac{1}{2}, 1[$ . 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  $\pi^D = \frac{\pi^M}{2}$ ,  $\frac{\pi^M}{\pi^M - \pi^D} = 2 > p_g + p_b$ ,  $\forall a \in [\frac{1}{2}, 1[$  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  $\pi^D \in [0, \frac{\pi^M}{2}]$ . 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**  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D) < p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M$ .

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

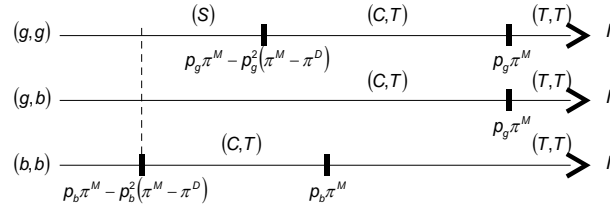


Figure 2. Case (ii):  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D) < p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M$

Similarly to case (i), we describe these equilibrium configurations of the ventures for case (ii) in lemma 2 (see Appendix A).

**Case (iii)**

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

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

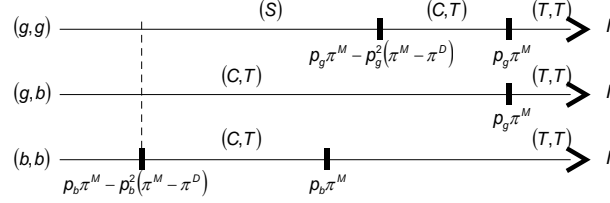


Figure 3. Case (iii):  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$  and  $p_b \pi^M < p_g \pi^M - p_g^2 (\pi^M - \pi^D)$

In lemma 3 the equilibrium configurations of the ventures for this case are described (see Appendix A).

**Case (iv)**

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

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

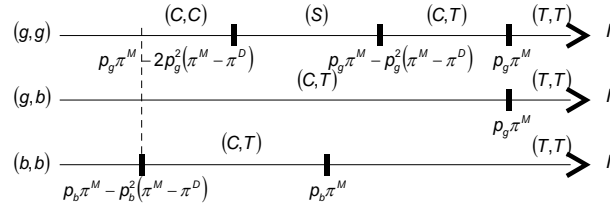


Figure 4. Case (iv):  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M < p_g \pi^M - p_g^2 (\pi^M - \pi^D)$

Lemma 4 describes the equilibrium configurations of the ventures for this case (see Appendix A).

**Case (v)**

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

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



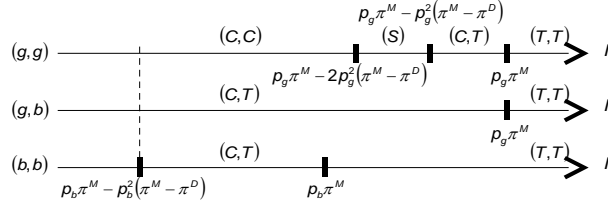


Figure 5. Case (v):  $p_b \pi^M < p_g \pi^M - 2p_g^2 (\pi^M - \pi^D)$

Lemma 5 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.

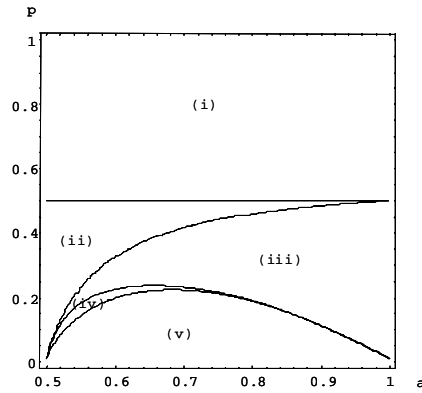


Figure 6. Cases (i) – (v) for strong competition, i.e.  $\pi^D = 0$ , as a function of  $p$  and  $a$ .

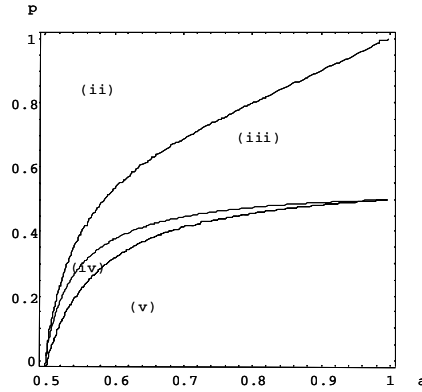


Figure 7. Cases (i)-(v) for lax competition, i.e.  $\pi^D = \frac{\pi^M}{2}$ , as a function of  $p$  and  $a$ .

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.

**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  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < I < p_g \pi^M$ , only one of them continues to invest while the other one drops out;

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

(iii) if  $I < p_g \pi^M - 2p_g^2 (\pi^M - \pi^D)$ , 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,  $\pi^D$  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,  $\pi^D$  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,  $\pi^D$ , 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.

## 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 Bayesian equilibria for the parameter regions in which truthtelling is not an equilibrium. We find that in these symmetric Bayesian equilibria, venture capitalists do not syndicate where they would have competed with public signals. On the contrary, in two of the Bayesian equilibria, 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 Bayesian equilibrium 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,  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$ , holds, i.e.  $\frac{\pi^M}{\pi^M - \pi^D} < p_g + p_b$ . It can be shown that for  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$  and  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_b \pi^M$ , a venture capitalist with a bad signal has an incentive to mimic one having a good signal. For  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$  and  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_b \pi^M$ , (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  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$  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.

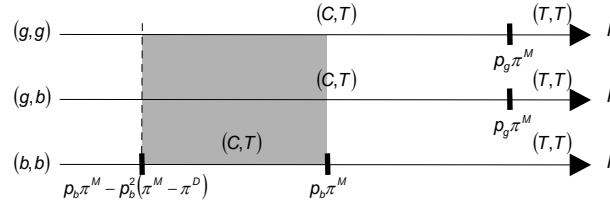


Figure 8. Case (i):  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$

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

Let  $s_1 = g$ . Then with probability  $\sigma_g$ , also  $s_2 = g$ , and the venture capitalists flip a coin to determine who continues and earns monopoly profits.<sup>7</sup> Maintaining the assumption that  $s_1 = g$ , if  $s_2 = b$ , which happens with probability  $\sigma_b$  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:

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

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

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

<sup>7</sup>Remember that  $\sigma_g$  and  $\sigma_b$  are respectively the probabilities of getting either a good or a bad signal.

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

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

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

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

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

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

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

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

As  $\sigma_g \frac{1}{2} (p_g \pi^M - I) + \sigma_b (p_g \pi^M - I) > \sigma_b (p_g \pi^M - I)$ , 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  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_b \pi^M$ , a venture capitalist with a bad signal would have an incentive to lie.

**Case (ii)** Remember that for this case assumption 3,  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D) < p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M$ , 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  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D) < p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M$  and  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_g \pi^M - p_g^2 (\pi^M - \pi^D)$ , a venture capitalist with a bad signal has an incentive to mimic one having a good signal. This means that, for  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D) < p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M$  and  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_g \pi^M - p_g^2 (\pi^M - \pi^D)$ , (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  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D) < p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M$  and  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < I < p_b \pi^M$ , a venture capitalist with a bad signal has an incentive to mimic one

having a good signal. For  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D)$  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.

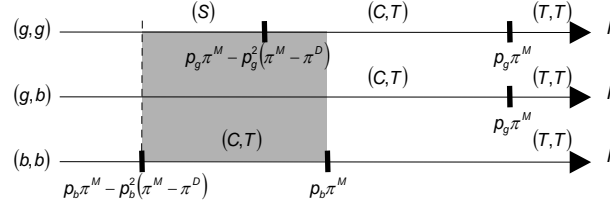


Figure 9. Case (ii):  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D) < p_g\pi^M - p_g^2(\pi^M - \pi^D) < p_b\pi^M$

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,  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D)$  and  $p_b\pi^M < p_g\pi^M - p_g^2(\pi^M - \pi^D)$ , holds, i.e.  $\frac{p_g^2}{p_g - p_b} < \frac{p_g^2}{\pi^M - \pi^D} < (p_g + p_b) + \frac{p_g^2}{p_g - p_b}$ .

It can be shown that for  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D)$  and  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < I < p_b\pi^M$ , a venture capitalist with a bad signal has an incentive to mimic one having a good signal. For  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D)$  and  $p_b\pi^M < I < p_g\pi^M - p_g^2(\pi^M - \pi^D)$ , 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  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D)$  and  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < I < p_g\pi^M$ , 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).

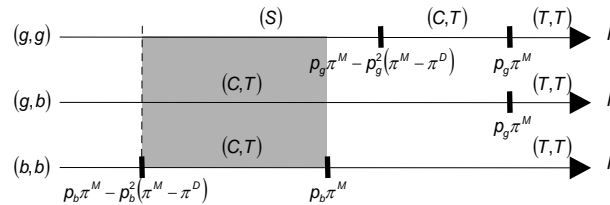


Figure 10. Case (iii):  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D)$  and  $p_b\pi^M < p_g\pi^M - p_g^2(\pi^M - \pi^D)$

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,  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M < p_g\pi^M - p_g^2(\pi^M - \pi^D)$ , 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  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M < p_g\pi^M - p_g^2(\pi^M - \pi^D)$  and  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < I < p_g\pi^M - 2p_g^2(\pi^M - \pi^D)$ , a venture capitalist with a bad signal has an incentive to mimic one with a good signal. For  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M < p_g\pi^M - p_g^2(\pi^M - \pi^D)$  and  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < I < p_b\pi^M$ , a venture capitalist with a bad signal has an incentive to mimic one with a good signal. For  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D)$  and  $p_b\pi^M < I < p_g\pi^M - p_g^2(\pi^M - \pi^D)$ , 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  $\frac{p_g + p_b}{2}\pi^M > p_g\pi^M - p_g^2(\pi^M - \pi^D) \Leftrightarrow \frac{\pi^M}{\pi^M - \pi^D} < \frac{2p_g^2}{p_g - p_b}$ , which is one of the conditions for case (iv) to exist. For  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < p_b\pi^M - p_b^2(\pi^M - \pi^D)$  and  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < I < p_g\pi^M$ , 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.

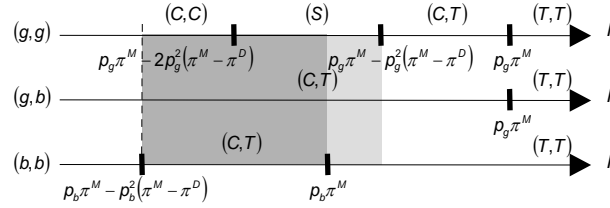


Figure 11. Case (iv):  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M < p_g\pi^M - p_g^2(\pi^M - \pi^D)$

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,  $p_b\pi^M < p_g\pi^M - 2p_g^2(\pi^M - \pi^D)$ , holds, i.e.  $\frac{2p_g^2}{p_g - p_b} < \frac{\pi^M}{\pi^M - \pi^D}$ .

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

$\frac{2p_g^2}{p_g - p_b}$ , which is one of the conditions for case (v) to exist. Finally, for  $p_b\pi^M < p_g\pi^M - 2p_g^2(\pi^M - \pi^D)$  and  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < I < p_g\pi^M$ , 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.

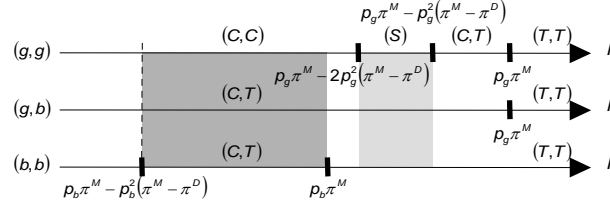


Figure 12. Case (v):  $p_b\pi^M < p_g\pi^M - 2p_g^2(\pi^M - \pi^D)$

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  $p \in [0, 1]$ ,  $a \in [\frac{1}{2}, 1[$ , if  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < I < p_b\pi^M$ , venture capitalists have an incentive to lie - sending untruthful messages - about having received bad signals. In addition, for  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < I < p_g\pi^M - p_g^2(\pi^M - \pi^D)$ , 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:

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

and as

$$p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < I < p_g\pi^M - p_g^2(\pi^M - \pi^D). \quad (\text{IC-Violation \#2})$$

Note that (IC-Violation #2) holds for larger investment levels than (IC-Violation#1) only in cases (iv) and (v). In cases (i) – (iii), it is either contained in (IC-Violation#1) or to the left of it, which is outside the range of interest as defined in assumption 1.

## 4.2 Bayesian Equilibria

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 and cannot be used in equilibrium. We therefore derive Bayesian equilibria that do not make use of the messages for the intervals where the incentive compatibility constraints are violated.



A typical strategy for the Bayesian equilibrium assigns an action to each signal a venture capitalist may receive. For each of the possible combinations of signals venture capitalists may receive, such an action is composed of two virtually sequential steps: first it needs to contain a recommendation on whether to syndicate (Yes), or not (No), and, second, if syndication is not agreed upon it needs to contain another recommendation about whether to continue investing into the idea (Stay), or to drop out instead (Drop).

For each  $VC_i$ , the following describes the set of the sixteen possible strategies to be played in this context:

1. (*Yes, Stay*) if  $s_i = \textit{good}$ ; (*Yes, Stay*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{Yes, Stay}), (\textit{Yes, Stay}))$
2. (*No, Stay*) if  $s_i = \textit{good}$ ; (*Yes, Stay*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{No, Stay}), (\textit{Yes, Stay}))$
3. (*Yes, Stay*) if  $s_i = \textit{good}$ ; (*No, Stay*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{Yes, Stay}), (\textit{No, Stay}))$
4. (*No, Stay*) if  $s_i = \textit{good}$ ; (*No, Stay*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{No, Stay}), (\textit{No, Stay}))$
5. (*Yes, Stay*) if  $s_i = \textit{good}$ ; (*Yes, Drop*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{Yes, Stay}), (\textit{Yes, Drop}))$
6. (*No, Stay*) if  $s_i = \textit{good}$ ; (*Yes, Drop*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{No, Stay}), (\textit{Yes, Drop}))$
7. (*Yes, Stay*) if  $s_i = \textit{good}$ ; (*No, Drop*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{Yes, Stay}), (\textit{No, Drop}))$
8. (*No, Stay*) if  $s_i = \textit{good}$ ; (*No, Drop*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{No, Stay}), (\textit{No, Drop}))$
9. (*Yes, Drop*) if  $s_i = \textit{good}$ ; (*Yes, Stay*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{Yes, Drop}), (\textit{Yes, Stay}))$
10. (*No, Drop*) if  $s_i = \textit{good}$ ; (*Yes, Stay*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{No, Drop}), (\textit{Yes, Stay}))$
11. (*Yes, Drop*) if  $s_i = \textit{good}$ ; (*No, Stay*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{Yes, Drop}), (\textit{No, Stay}))$
12. (*No, Drop*) if  $s_i = \textit{good}$ ; (*No, Stay*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{No, Drop}), (\textit{No, Stay}))$
13. (*Yes, Drop*) if  $s_i = \textit{good}$ ; (*Yes, Drop*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{Yes, Drop}), (\textit{Yes, Drop}))$
14. (*No, Drop*) if  $s_i = \textit{good}$ ; (*Yes, Drop*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{No, Drop}), (\textit{Yes, Drop}))$
15. (*Yes, Drop*) if  $s_i = \textit{good}$ ; (*No, Drop*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{Yes, Drop}), (\textit{No, Drop}))$
16. (*No, Drop*) if  $s_i = \textit{good}$ ; (*No, Drop*) if  $s_i = \textit{bad}$ , indicated as  $((\textit{No, Drop}), (\textit{No, Drop}))$

Different payoffs for each venture capitalist can be assigned for each combination of those strategies that can be played for any realized pair of signals  $(s_1, s_2)$ . The matrices below, represent those realized payoffs respectively for  $VC_1$ , the first payoff of each cell, and  $VC_2$ , the second one in each cell:

$(s_1, s_2) = (g, g)$	Yes, Stay	No, Stay	Yes, Drop	No, Drop
Yes, Stay	$\frac{1}{2}(p_g \pi^M - I)$ $\frac{1}{2}(p_g \pi^M - I)$	$p_g^2 \pi^D + p_g(1 - p_g) \pi^M - I$ $p_g^2 \pi^D + p_g(1 - p_g) \pi^M - I$	$\frac{1}{2}(p_g \pi^M - I)$ $\frac{1}{2}(p_g \pi^M - I)$	$p_g \pi^M - I$ 0
No, Stay	$p_g^2 \pi^D + p_g(1 - p_g) \pi^M - I$ $p_g^2 \pi^D + p_g(1 - p_g) \pi^M - I$	$p_g^2 \pi^D + p_g(1 - p_g) \pi^M - I$ $p_g^2 \pi^D + p_g(1 - p_g) \pi^M - I$	$p_g \pi^M - I$ 0	$p_g \pi^M - I$ 0
Yes, Drop	$\frac{1}{2}(p_g \pi^M - I)$ $\frac{1}{2}(p_g \pi^M - I)$	0 $p_g \pi^M - I$	$\frac{1}{2}(p_g \pi^M - I)$ $\frac{1}{2}(p_g \pi^M - I)$	0 0
No, Drop	0 $p_g \pi^M - I$	0 $p_g \pi^M - I$	0 0	0 0

$(s_1, s_2) = (g, b)$	Yes, Stay	No, Stay	Yes, Drop	No, Drop
Yes, Stay	$\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$ $\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$	$p_g p_b \pi^D + p_g(1 - p_b) \pi^M - I$ $p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$	$\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$ $\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$	$p_g \pi^M - I$ 0
No, Stay	$p_g p_b \pi^D + p_g(1 - p_b) \pi^M - I$ $p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$	$p_g p_b \pi^D + p_g(1 - p_b) \pi^M - I$ $p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$	$p_g \pi^M - I$ 0	$p_g \pi^M - I$ 0
Yes, Drop	$\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$ $\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$	0 $p_b \pi^M - I$	$\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$ $\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$	0 0
No, Drop	0 $p_b \pi^M - I$	0 $p_b \pi^M - I$	0 0	0 0

$(s_1, s_2) = (b, g)$	Yes, Stay	No, Stay	Yes, Drop	No, Drop
Yes, Stay	$\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$ $\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$	$p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$ $p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$	$\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$ $\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$	$p_b \pi^M - I$ 0
No, Stay	$p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$ $p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$	$p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$ $p_b p_g \pi^D + p_b(1 - p_g) \pi^M - I$	$p_b \pi^M - I$ 0	$p_b \pi^M - I$ 0
Yes, Drop	$\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$ $\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$	0 $p_g \pi^M - I$	$\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$ $\frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right)$	0 0
No, Drop	0 $p_g \pi^M - I$	0 $p_g \pi^M - I$	0 0	0 0

$(s_1, s_2) = (b, b)$	Yes, Stay	No, Stay	Yes, Drop	No, Drop
Yes, Stay	$\frac{1}{2}(p_b \pi^M - I)$ $\frac{1}{2}(p_b \pi^M - I)$	$p_b^2 \pi^D + p_b(1 - p_b) \pi^M - I$ $p_b^2 \pi^D + p_b(1 - p_b) \pi^M - I$	$\frac{1}{2}(p_b \pi^M - I)$ $\frac{1}{2}(p_b \pi^M - I)$	$p_b \pi^M - I$ 0
No, Stay	$p_b^2 \pi^D + p_b(1 - p_b) \pi^M - I$ $p_b^2 \pi^D + p_b(1 - p_b) \pi^M - I$	$p_b^2 \pi^D + p_b(1 - p_b) \pi^M - I$ $p_b^2 \pi^D + p_b(1 - p_b) \pi^M - I$	$p_b \pi^M - I$ 0	$p_b \pi^M - I$ 0
Yes, Drop	$\frac{1}{2}(p_b \pi^M - I)$ $\frac{1}{2}(p_b \pi^M - I)$	0 $p_b \pi^M - I$	$\frac{1}{2}(p_b \pi^M - I)$ $\frac{1}{2}(p_b \pi^M - I)$	0 0
No, Drop	0 $p_b \pi^M - I$	0 $p_b \pi^M - I$	0 0	0 0

#### 4.2.1 Symmetric Equilibria

For tractability, and given the symmetric nature of the model, we will restrict our attention to candidates for symmetric equilibria only. When looking at possible symmetric Bayesian equilibria, there are 16 equilibrium

candidates to be explored. We show in Appendix C that only 4 out of these 16 candidates are indeed possible Bayesian equilibria. The conditions for which those 4 are indeed Bayesian equilibria, are specified below.

**Equilibrium 1:** (((Yes, Stay), (Yes, Drop)), ((Yes, Stay), (Yes, Drop))) This strategy profile is a Bayesian equilibrium under the conditions

$$I > p_g \pi^M - 2\sigma_g p_g^2 (\pi^M - \pi^D) + \frac{1}{2} (p_g - p) \pi^M \quad (\text{Eq. 1-1})$$

and

$$I > p_b \pi^M - 2\sigma_g p_g p_b (\pi^M - \pi^D) - \frac{1}{2} (p - p_b) \pi^M. \quad (\text{Eq. 1-2})$$

In Equilibrium 1, i.e. (((Yes, Stay), (Yes, Drop)), ((Yes, Stay), (Yes, Drop))), the venture capitalists always syndicate.

**Equilibrium 2:** (((No, Stay), (Yes, Drop)), ((No, Stay), (Yes, Drop))) This strategy profile is a Bayesian equilibrium under the conditions

$$\frac{3p_g - p_b}{2} \pi^M > I \quad (\text{Eq. 2-1})$$

and

$$I > p_b \pi^M - 2 \frac{\sigma_g}{1 + \sigma_g} p_b p_g (\pi^M - \pi^D). \quad (\text{Eq. 2-2})$$

In Equilibrium 2, i.e., in (((No, Stay), (Yes, Drop)), ((No, Stay), (Yes, Drop))), the venture capitalists compete if both receive a good signal, if only one receives a good signal and the other one receives a bad signal, only the one with the good signal continues, and they syndicate if both receive a bad signal. However, this equilibrium is not credible as after observing the other venture capitalist's willingness or unwillingness to syndicate, it would be possible to infer her signal. As truthtelling is not incentive compatible, this equilibrium does not survive if we solve for a *perfect* Bayesian equilibrium. We will therefore disregard it.

**Equilibrium 3:** (((No, Stay), (No, Drop)), ((No, Stay), (No, Drop))) This strategy profile is a Bayesian equilibrium under the conditions

$$p_g \pi^M - \sigma_g p_g^2 (\pi^M - \pi^D) > I \quad (\text{Eq. 3-1})$$

and

$$p_b \pi^M - \sigma_g p_b p_g (\pi^M - \pi^D) < I. \quad (\text{Eq. 3-2})$$

In Equilibrium 3, i.e., (((No, Stay), (No, Drop)), ((No, Stay), (No, Drop))), the venture capitalists compete if both receive a good signal, if only one receives a good signal and the other one receives a bad signal, only the one with the good signal continues, and they both terminate if both receive a bad signal.

**Equilibrium 4:** (((Yes, Drop), (Yes, Stay)), ((Yes, Drop), (Yes, Stay))) This strategy profile is a Bayesian equilibrium under the conditions

$$I > p_g \pi^M - 2\sigma_b p_g p_b (\pi^M - \pi^D) + \sigma_b \frac{p_g - p_b}{2} \pi^M \quad (\text{Eq. 4-1})$$

and

$$I > p_b \pi^M - 2\sigma_b p_b^2 (\pi^M - \pi^D) + \sigma_g \frac{p_b - p_g}{2} \pi^M. \quad (\text{Eq. 4-2})$$

In Equilibrium 4, i.e., (((No, Stay), (No, Drop)), ((No, Stay), (No, Drop))), the venture capitalists always syndicate.

Now that we have characterized the conditions for those equilibria to exist, we check whether these equilibrium conditions are compatible with the conditions for which the truth-telling incentive compatibility constraints were violated.

We start with *Equilibrium 1*. Note that, for any  $p \in (0, 1)$  and  $a \in [\frac{1}{2}, 1[$ , the minimum investment level required by (Eq. 1-2) is smaller than the minimum investment level relevant for our analysis (see assumption 1), which coincides with the left end of the interval for (IC-Violation #1)<sup>8</sup>. Therefore, (Eq. 1-2) holds in the whole interval under consideration and we can ignore it in the remainder of the analysis.

Let us first turn to (IC-Violation #2). Here, we find that (Eq. 1-1) is incompatible with (IC-Violation #2) whenever we are in cases (iv) and (v), as  $p_g \pi^M - 2\sigma_g p_g^2 (\pi^M - \pi^D) + \frac{1}{2} (p_g - p) \pi^M < p_g \pi^M - p_g^2 (\pi^M - \pi^D)$  holds only for regions in the  $a - p$  space for which cases (iv) and (v) do not exist. We can therefore state the following:

**Remark 3** *In cases (iv) and (v), for  $I \in [p_g \pi^M - 2p_g^2 (\pi^M - \pi^D), p_g \pi^M - p_g^2 (\pi^M - \pi^D)]$ , Equilibrium 1 does not exist, irrespective of the degree of competition.*

Let us now turn to (IC-Violation #1). Now, note that Equilibrium 1 exists in (IC-Violation #1), as long as

$$p_b \pi^M - p_b^2 (\pi^M - \pi^D) > p_g \pi^M - 2\sigma_g p_g^2 (\pi^M - \pi^D) + \frac{1}{2} (p_g - p) \pi^M.$$

This holds in the areas labelled as (1a) in both figures 13 (for strong competition) and 14 (for lax competition), which are situated in each figure above the upper green line. Note, furthermore, that Equilibrium 1 does not exist in the interval (IC-Violation #1), as long as

$$p_g \pi^M - 2\sigma_g p_g^2 (\pi^M - \pi^D) + \frac{1}{2} (p_g - p) \pi^M > p_b \pi^M.$$

This holds in the areas labelled as (1c) in both figures 13 (for strong competition) and 14 (for lax competition), which are situated in each figure below the lower green line. In addition to these areas, we have included in figures 13 and 14 the areas for which cases (i) – (v) exist, divided by black solid lines.

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<sup>8</sup>  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) > p_b \pi^M - 2\sigma_g p_g p_b (\pi^M - \pi^D) - \frac{1}{2} (p - p_b) \pi^M \Leftrightarrow \frac{\pi^M}{\pi^M - \pi^D} > \frac{p_b^2 - 2\sigma_g p_g p_b}{\frac{1}{2}(p - p_b)} \forall p \in [0, 1] \forall a \in [\frac{1}{2}, 1[$ .

The observations made here lead to the following result:

**Remark 4** For (IC-Violation #1), i.e., for  $I \in [p_b \pi^M - p_b^2 (\pi^M - \pi^D), p_b \pi^M]$ ,

1. and  $\pi^D = 0$ , Equilibrium 1 does not exist in cases (iii) - (v), the least competitive equilibria, it exists in case (ii) only for sufficiently high  $p$  and  $I$  (area 1b), it exists in case (i) for sufficiently high  $p$  and any  $I$  (area 1a), and if  $p$  is insufficiently high, then it exists for sufficiently high  $I$  (area 1b). It does not exist otherwise (area 1c);
2. and  $\pi^D = \frac{\pi^M}{2}$ , Equilibrium 1 does not exist in cases (iv) and (v), it exists in cases (i) - (iii) for sufficiently high  $p$  and any  $I$  (area 1a), and if  $p$  is insufficiently high, then it exists for sufficiently high  $I$  (area 1b). It does not exist otherwise (area 1c).

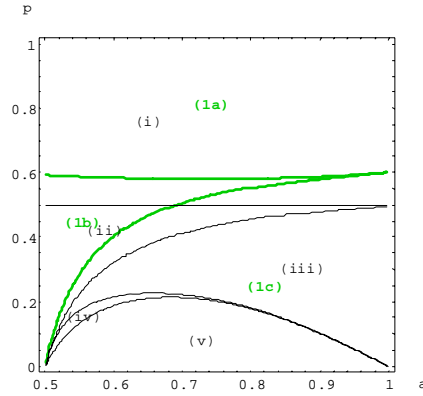


Figure 13: Existence of equilibrium 1 for  $p_b \pi^M \leq I \leq p_b \pi^M - p_b^2 (\pi^M - \pi^D)$  for strong competition ( $\pi^D = 0$ ).

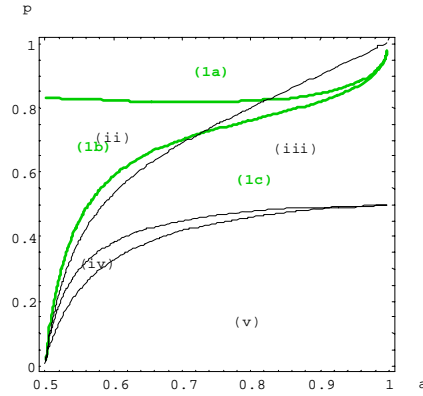


Figure 14: Existence of equilibrium 1 for  $p_b \pi^M \leq I \leq p_b \pi^M - p_b^2 (\pi^M - \pi^D)$  for lax competition ( $\pi^D = \pi^M/2$ ).

Equilibrium 1, where venture capitalists always syndicate their investments, only exists in intervals where they would have continued one project only with public signals as well. In other words, having private signals does not have detrimental effects for competition in Equilibrium 1.

Let us turn to *Equilibrium 3*. Note that in (IC-Violation #2), both (Eq. 3-1) and (Eq. 3-2) hold. This is so because: (1) the upper bound of (IC-Violation #2) is smaller than the maximum investment for Equilibrium 3 to exist, i.e.,

$$p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_g \pi^M - \sigma_g p_g^2 (\pi^M - \pi^D);$$

and, (2) the lower bound of (IC-Violation #2) in cases (iv) and (v), is larger than the minimum investment level for Equilibrium 3 to exist, i.e.,

$$p_b \pi^M - \sigma_g p_b p_g (\pi^M - \pi^D) < p_b \pi^M.$$

Therefore, the following result holds:

**Remark 5** *In cases (iv) and (v), if  $I \in [p_g \pi^M - 2p_g^2 (\pi^M - \pi^D), p_g \pi^M - p_g^2 (\pi^M - \pi^D)]$ , Equilibrium 3 exists for all degrees of competition.*

Let us turn to (IC-Violation #1). Comparing (Eq. 3-1) and (Eq. 3-2) with the boundaries of (IC-Violation#1), we are left with five different scenarios, (3a)-(3e), which we depict in figure 17. The cutoff points in the figure are defined as follows: 1 and 2 refer to the boundaries of (IC-Violation #1), i.e.,  $1 := p_b \pi^M - p_b^2 (\pi^M - \pi^D)$  and  $2 := p_b \pi^M$ ; 3 refers to the minimum investment level for which Equilibrium 3 exists, i.e.,  $3 := p_b \pi^M - \sigma_g p_b p_g (\pi^M - \pi^D)$ ; and, finally, 4 refers to the maximum investment level for which Equilibrium 3 exists, i.e.,  $4 := p_g \pi^M - \sigma_g p_g^2 (\pi^M - \pi^D)$ .

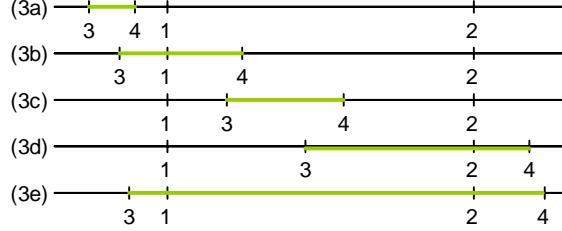


Figure 17. Equilibrium 3 exists for  $I$  in the green intervals.

Comparing the cutoffs for different values of  $a$  and  $p$ , as well as for various degrees of competition, we can state the following result, which is also represented graphically in figures 18 (for strong competition) and 19 (for lax competition).

**Remark 6** *For  $I \in [p_b \pi^M - p_b^2 (\pi^M - \pi^D), p_b \pi^M]$*

1. *and  $\pi^D = 0$ , Equilibrium 3 always exists for sufficiently high  $a$  and sufficiently low  $p$  (area 3e); it exists for sufficiently high  $I$  for low  $p$  if  $a$  is too low (area 3d); it exists for intermediate values of  $I$  if  $a$  is low and  $p$  sufficiently high (area 3c); it exists for sufficiently low  $I$  if  $p$  and  $a$  take intermediate values (area 3b); and, it does not exist if both  $a$  and  $p$  are too high (area 3a);*

2. and  $\pi^D = \frac{\pi^M}{2}$ , *Equilibrium 3* always exists for some  $I$ . It always exists for sufficiently high  $a$  and sufficiently low  $p$  (area 3e); it exists for sufficiently high  $I$  for low  $p$  if  $a$  is too low (area 3d); it exists for intermediate values of  $I$  if  $a$  is low and  $p$  sufficiently high (area 3c); and, it exists for sufficiently low  $I$  if  $p$  and  $a$  take sufficiently high values (area 3b).

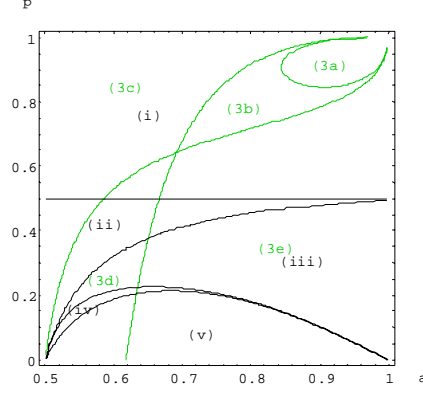


Figure 18. Existence of Equilibrium 3 for strong competition.

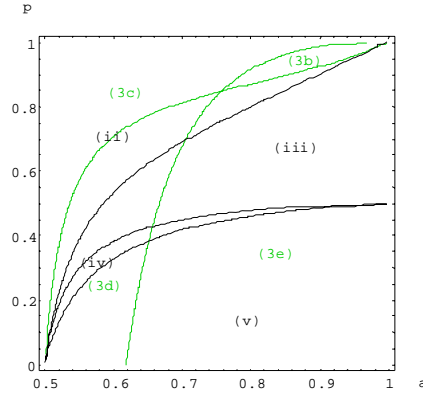


Figure 19. Existence of Equilibrium 3 for lax competition.

Interestingly, there are, therefore, situations (in areas (ii)–(v)) where, by playing Equilibrium 3, venture capitalists would compete if both received a good signal,  $(s_1, s_2) = (g, g)$ , where they would have syndicated instead with public signals.

Let us finally examine *Equilibrium 4*. Note first that (Eq. 4-2) holds whenever (Eq. 4-1) does, as

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

Therefore, we can ignore (Eq. 4-2) here.

First, note that the minimum investment for Equilibrium 4's existence exceeds the maximum investment in (IC-Violation #2), i.e.,

$$p_g \pi^M - 2\sigma_b p_g p_b (\pi^M - \pi^D) + \sigma_b \frac{p_g - p_b}{2} \pi^M > p_g \pi^M - p_g^2 (\pi^M - \pi^D).$$

We therefore have the following result:

**Remark 7** *In cases (iv) and (v), for  $I \in [p_g \pi^M - 2p_g^2 (\pi^M - \pi^D), p_g \pi^M - p_g^2 (\pi^M - \pi^D)]$ , Equilibrium 4 does not exist, irrespective of the degree of competition.*

Second, note that the minimum investment for Equilibrium 4's existence exceeds the minimum investment in (IC-Violation #1), i.e.,

$$p_g \pi^M - 2\sigma_b p_g p_b (\pi^M - \pi^D) + \sigma_b \frac{p_g - p_b}{2} \pi^M > p_b \pi^M - p_b^2 (\pi^M - \pi^D).$$

This means that for small investment levels in (IC-Violation #1), Equilibrium 4 does not exist. In fact, it does not exist in (IC-Violation #1) as long as the minimum investment for Equilibrium 4's existence is larger than the maximum investment in (IC-Violation #1), i.e., as long as

$$p_g \pi^M - 2\sigma_b p_g p_b (\pi^M - \pi^D) + \sigma_b \frac{p_g - p_b}{2} \pi^M > p_b \pi^M.$$

This inequality holds in the areas labelled as (4b) in both figures 20 (for strong competition) and 21 (for lax competition), which are situated in each figure below the green line. Therefore, Equilibrium 4 does not exist in (4b) and it exists for  $I \geq p_g \pi^M - 2\sigma_b p_g p_b (\pi^M - \pi^D) + \sigma_b \frac{p_g - p_b}{2} \pi^M$  in (4a).

**Remark 8** *For  $I \in [p_b \pi^M - p_b^2 (\pi^M - \pi^D), p_b \pi^M]$ , irrespective of the degree of competition, Equilibrium 4 does not exist in cases (iii) – (v), the least competitive equilibria, it exists in cases (i) and (ii) for sufficiently large  $p$  and  $I$  (area 4a).*

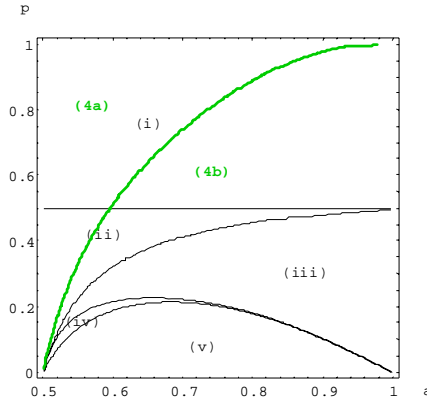


Figure 20. Existence of Equilibrium 4 for strong competition.



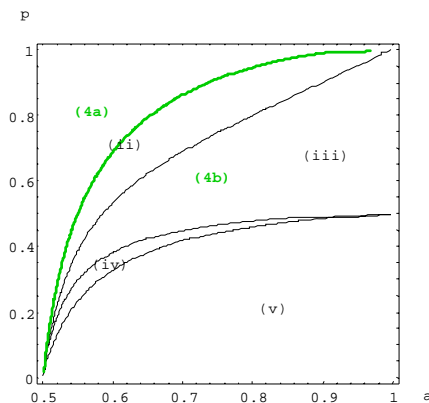


Figure 21. Existence of Equilibrium 4 for tax competition.

Equilibrium 4, where venture capitalists always syndicate their investments, only exists in intervals where they would have continued one project only with public signals as well. In other words, having private signals also does not have detrimental effects for competition in Equilibrium 4, similarly to the situation in Equilibrium 1.

These results can be summarized in the following proposition:

**Proposition 3** *With private signals, in the symmetric Bayesian equilibria, (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 one of the symmetric Bayesian equilibria, both venture capitalists drop out if both receive a bad signal, whereas one of them would have continued alone with public signals.*

## 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 1** *In equilibrium, if  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$  and*

1.  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_b \pi^M$ , 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 2** *In equilibrium, if  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D) < p_g \pi^M - p_g^2 (\pi^M - \pi^D) < p_b \pi^M$  and*

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

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

1.  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_b \pi^M$ , 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.  $p_b \pi^M < I < p_g \pi^M - p_g^2 (\pi^M - \pi^D)$ , 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.  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < I < p_g \pi^M$ , 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 4** *In equilibrium, if  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < p_b\pi^M < p_g\pi^M - p_g^2(\pi^M - \pi^D)$  and*

1.  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < I < p_g\pi^M - 2p_g^2(\pi^M - \pi^D)$ , 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.  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < I < p_b\pi^M$ , 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.  $p_b\pi^M < I < p_g\pi^M - p_g^2(\pi^M - \pi^D)$ , 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.  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < I < p_g\pi^M$ , 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 5** *In equilibrium, if  $p_b\pi^M < p_g\pi^M - 2p_g^2(\pi^M - \pi^D)$  and*

1.  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < I < p_b\pi^M$ , 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.  $p_b\pi^M < I < p_g\pi^M - 2p_g^2(\pi^M - \pi^D)$ , 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.  $p_g\pi^M - 2p_g^2(\pi^M - \pi^D) < I < p_g\pi^M - p_g^2(\pi^M - \pi^D)$ , 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.  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < I < p_g\pi^M$ , 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  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < I < p_g\pi^M - p_g^2(\pi^M - \pi^D)$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

\* 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  $p_b\pi^M - p_b^2(\pi^M - \pi^D) < I < p_b\pi^M$

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

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

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

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

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

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

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

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

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

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

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

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

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

\* 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  $p_g\pi^M - p_g^2(\pi^M - \pi^D) < I < p_g\pi^M$

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

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

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

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

\* 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  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_g \pi^M - 2p_g^2 (\pi^M - \pi^D)$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

\* 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  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < I < p_b \pi^M$

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

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

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

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

\* 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  $p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I < p_b \pi^M$



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

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

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

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

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

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

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

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

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

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

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

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

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

- \* 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  $p_g \pi^M - 2p_g^2 (\pi^M - \pi^D) < I < p_g \pi^M - p_g^2 (\pi^M - \pi^D)$

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

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

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

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

\* 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  $p_g \pi^M - p_g^2 (\pi^M - \pi^D) < I < p_g \pi^M$

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

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

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

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

\* 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 Equilibrium Candidates

Expected Payoffs if the other plays ((*Yes, Stay*), (*Yes, Stay*))

1.  $s_1 = g$

(a) (**Yes, Stay**)

$$\begin{aligned} & \sigma_g \frac{1}{2} (p_g \pi^M - I) + \sigma_b \frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right) \\ = & \frac{1}{2} \left( \sigma_g p_g \pi^M - \sigma_g I + \sigma_b \frac{p_g + p_b}{2} \pi^M - \sigma_b I \right) \\ = & \frac{1}{2} \left( \sigma_g p_g \pi^M - \sigma_g I + (1 - \sigma_g) \frac{p_g}{2} \pi^M + \frac{\sigma_b p_b}{2} \pi^M - \sigma_b I \right) \\ = & \frac{1}{2} \left( \frac{p_g}{2} \pi^M + \frac{p}{2} \pi^M + a p \pi^M - \frac{a p}{2} \pi^M - \frac{a p}{2} \pi^M - I \right) \\ = & \frac{1}{2} \left( \frac{p_g + p}{2} \pi^M - I \right) \end{aligned}$$

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) **(Yes, Stay)**

$$\begin{aligned} & \sigma_g \frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right) + \sigma_b \frac{1}{2} (p_b \pi^M - I) \\ = & \frac{1}{2} \left( \sigma_g \frac{p_g + p_b}{2} \pi^M - \sigma_g I + \sigma_b p_b \pi^M - \sigma_b I \right) \\ = & \frac{1}{2} \left( \frac{ap}{2} \pi^M + \frac{p_b}{2} \pi^M - \frac{(1-a)p}{2} \pi^M + (1-a)p \pi^M - I \right) \\ = & \frac{1}{2} \left( \frac{ap}{2} \pi^M + \frac{ap}{2} \pi^M - ap \pi^M + \frac{p_b}{2} \pi^M - \frac{p}{2} \pi^M + p \pi^M - I \right) \\ = & \frac{1}{2} \left( \frac{p_b + p}{2} \pi^M - I \right) \end{aligned}$$

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

3. (((*Yes, Stay*), (*Yes, Stay*)), ((*Yes, Stay*), (*Yes, Stay*))) is not an equilibrium as it requires

$$\begin{aligned}
\sigma_g \frac{1}{2} (p_g \pi^M - I) + \sigma_b \frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right) &\geq \sigma_g (p_g^2 \pi^D + p_g (1 - p_g) \pi^M - I) \\
&\quad + \sigma_b (p_g p_b \pi^D + p_g (1 - p_b) \pi^M - I) \\
\frac{1}{2} \left( \frac{p_g + p}{2} \pi^M - I \right) &\geq p_g p \pi^D + p_g (1 - p) \pi^M - I \\
\frac{p_g + p}{2} \pi^M - I &\geq 2p_g p \pi^D + 2p_g (1 - p) \pi^M - 2I \\
I &\geq 2p_g p \pi^D - 2p_g p \pi^M + 2p_g \pi^M - \frac{p_g}{2} \pi^M - \frac{p}{2} \pi^M \\
I &\geq \frac{3p_g - p}{2} \pi^M - 2p_g p (\pi^M - \pi^D)
\end{aligned}$$

and

$$\begin{aligned}
\sigma_g \frac{1}{2} \left( \frac{p_g + p_b}{2} \pi^M - I \right) + \sigma_b \frac{1}{2} (p_b \pi^M - I) &\geq \sigma_g (p_b p_g \pi^D + p_b (1 - p_g) \pi^M - I) \\
&\quad + \sigma_b (p_b^2 \pi^D + p_b (1 - p_b) \pi^M - I) \\
\frac{1}{2} \left( \frac{p_b + p}{2} \pi^M - I \right) &\geq p_b p \pi^D + p_b (1 - p) \pi^M - I \\
I &\geq 2p_b p \pi^D + 2p_b (1 - p) \pi^M - \frac{p_b + p}{2} \pi^M \\
I &\geq 2p_b p \pi^D - 2p_b p \pi^M + 2p_b \pi^M - \frac{p_b}{2} \pi^M - \frac{p}{2} \pi^M \\
I &\geq \frac{3p_b - p}{2} \pi^M - 2p_b p (\pi^M - \pi^D)
\end{aligned}$$

and as

$$p_b \pi^M - p_b^2 (\pi^M - \pi^D) < I$$

by assumption 1, and

$$\frac{3p_b - p}{2} \pi^M - 2p_b p (\pi^M - \pi^D) < p_b \pi^M - p_b^2 (\pi^M - \pi^D)$$

we have

$$\frac{3p_b - p}{2} \pi^M - 2p_b p (\pi^M - \pi^D) < I$$

**Expected Payoffs if the other plays ((*No, Stay*), (*Yes, Stay*))**

1.  $s_1 = g$

(a) (*Yes, Stay*)

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

(b) (*Yes, Drop*)

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

(c) **(No, Stay)**

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) **(Yes, Stay)**

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

3. (((No, Stay), (Yes, Stay)), ((No, Stay), (Yes, Stay))) is not an equilibrium because

$$\sigma_g \underbrace{(p_b p_g \pi^D + p_b (1 - p_g) \pi^M - I)}_{<0} + \sigma_b \frac{1}{2} (p_b \pi^M - I) < \sigma_g \cdot 0 + \sigma_b \frac{1}{2} (p_b \pi^M - I)$$

**Expected Payoffs if the other plays ((Yes, Stay), (No, Stay))**

1.  $s_1 = g$

(a) **(Yes, Stay)**

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) **(No, Stay)**

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

(d) (No, Drop)

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

3. (((Yes, Stay), (No, Stay)), ((Yes, Stay), (No, Stay))) is not an equilibrium because

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

**Expected Payoffs if the other plays ((No, Stay), (No, Stay))**

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) **(No, Stay)**

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) **(No, Stay)**

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

(d) (No, Drop)

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

3. (((No, Stay), (No, Stay)), ((No, Stay), (No, Stay))) is not an equilibrium because

$$\sigma_g \underbrace{(p_b p_g \pi^D + p_b (1 - p_g) \pi^M - I)}_{<0} + \sigma_b \underbrace{(p_b^2 \pi^D + p_b (1 - p_b) \pi^M - I)}_{<0} < \sigma_g \cdot 0 + \sigma_b \cdot 0$$

**Expected Payoffs if the other plays ((Yes, Stay), (Yes, Drop))**

1.  $s_1 = g$

(a) **(Yes, Stay)**

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) **(Yes, Drop)**

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

(c) (No, Stay)

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

(d) (No, Drop)

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

3. (((Yes, Stay), (Yes, Drop)), ((Yes, Stay), (Yes, Drop))) is an equilibrium if

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

and

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

**Expected Payoffs if the other plays ((No, Stay), (Yes, Drop))**



1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) **(No, Stay)**

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) **(Yes, Drop)**

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

(c) (No, Stay)

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

(d) (No, Drop)

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

3.  $((No, Stay), (Yes, Drop)), ((No, Stay), (Yes, Drop))$  is an equilibrium if

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

$$\sigma_b p_g \pi^M - \sigma_b \frac{1}{2} \frac{p_g + p_b}{2} \pi^M > \frac{\sigma_b}{2} I$$

$$2p_g \pi^M - \frac{p_g + p_b}{2} \pi^M > I$$

$$\frac{3p_g - p_b}{2} \pi^M > I$$

and

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

**Expected Payoffs if the other plays ((Yes, Stay), (No, Drop))**

1.  $s_1 = g$

(a) **(Yes, Stay)**

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

(b) **(Yes, Drop)**

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

(c) **(No, Stay)**

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

(d) **(No, Drop)**

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

2.  $s_1 = b$

(a) **(Yes, Stay)**

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

(b) **(Yes, Drop)**

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

(c) **(No, Stay)**

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

(d) **(No, Drop)**

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

3. (((Yes, Stay), (No, Drop)), ((Yes, Stay), (No, Drop))) is not an equilibrium because

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

**Expected Payoffs if the other plays ((No, Stay), (No, Drop))**

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) **(No, Stay)**

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) **(No, Drop)**

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

3. (((No, Stay), (No, Drop)), ((No, Stay), (No, Drop))) is an equilibrium if

$$\sigma_g (p_g^2 \pi^D + p_g (1 - p_g) \pi^M - I) + \sigma_b (p_g \pi^M - I) > 0$$

$$\sigma_g p_g \pi^M + \sigma_b p_g \pi^M + \sigma_g p_g^2 \pi^D - \sigma_g p_g^2 \pi^M > I$$

$$p_b \pi^M - \sigma_g p_g^2 (\pi^M - \pi^D) > I$$

and

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

$$\sigma_g p_b \pi^M + \sigma_b p_b \pi^M + \sigma_g p_b p_g \pi^D - \sigma_g p_b p_g \pi^M < I$$

$$p_b \pi^M - \sigma_g p_b p_g (\pi^M - \pi^D) < I$$

**Expected Payoffs if the other plays ((Yes, Drop), (Yes, Stay))**

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

3. (((Yes, Drop), (Yes, Stay)), ((Yes, Drop), (Yes, Stay))) is an equilibrium if

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

and

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

**Expected Payoffs if the other plays ((No, Drop), (Yes, Stay))**

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) **(No, Drop)**

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

2.  $s_1 = b$

(a) **(Yes, Stay)**

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

3. (((No, Drop), (Yes, Stay)), ((No, Drop), (Yes, Stay))) is not an equilibrium as

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

**Expected Payoffs if the other plays ((Yes, Drop), (No, Stay))**

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) (No, Drop)

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

3. (((Yes, Drop), (No, Stay)), ((Yes, Drop), (No, Stay))) is not an equilibrium as it would require

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

and

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

by assumption 1, we have

$$p_b \pi^M - p_b^2 (\pi^M - \pi^D) \leq I$$

which contradicts the condition

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

as

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

### Expected Payoffs if the other plays ((No, Drop), (No, Stay))

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

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

(d) **(No, Drop)**

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) **(No, Stay)**

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

(d) (No, Drop)

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

3. (((No, Drop), (No, Stay)), ((No, Drop), (No, Stay))) is not an equilibrium as it would require

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

and

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

which is not possible.

**Expected Payoffs if the other plays ((Yes, Drop), (Yes, Drop))**

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) **(Yes, Drop)**

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

(c) (No, Stay)

$$\sigma_g (p_g \pi^M - I) + \sigma_b (p_g \pi^M - I)$$



(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) **(Yes, Drop)**

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

(c) (No, Stay)

$$\sigma_g (p_b \pi^M - I) + \sigma_b (p_b \pi^M - I)$$

(d) (No, Drop)

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

3. (((Yes, Drop), (Yes, Drop)), ((Yes, Drop), (Yes, Drop))) is not an equilibrium as

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

**Expected Payoffs if the other plays ((No, Drop), (Yes, Drop))**

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

$$\sigma_g (p_g \pi^M - I) + \sigma_b (p_g \pi^M - I)$$

(d) **(No, Drop)**

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

2.  $s_1 = b$

(a) **(Yes, Stay)**

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

(b) (Yes, Drop)

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

(c) (No, Stay)

$$\sigma_g (p_b \pi^M - I) + \sigma_b (p_b \pi^M - I)$$

(d) (No, Drop)

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

3. (((No, Drop), (Yes, Drop)), ((No, Drop), (Yes, Drop))) is not an equilibrium as

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

**Expected Payoffs if the other plays ((Yes, Drop), (No, Drop))**

1.  $s_1 = g$

(a) (Yes, Stay)

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

(b) **(Yes, Drop)**

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

(c) (No, Stay)

$$\sigma_g (p_g \pi^M - I) + \sigma_b (p_g \pi^M - I)$$

(d) (No, Drop)

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

2.  $s_1 = b$

(a) (Yes, Stay)

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

(b) (Yes, Drop)

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

(c) (No, Stay)

$$\sigma_g (p_b \pi^M - I) + \sigma_b (p_b \pi^M - I)$$

(d) **(No, Drop)**

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

3. (((*Yes, Drop*), (*No, Drop*)), ((*Yes, Drop*), (*No, Drop*))) is not an equilibrium as

$$\sigma_g \frac{1}{2} (p_g \pi^M - I) + \sigma_b \cdot 0 < \sigma_g \frac{1}{2} (p_g \pi^M - I) + \underbrace{\sigma_b (p_g \pi^M - I)}_{>0}$$

**Expected Payoffs if the other plays ((*No, Drop*), (*No, Drop*))**

1.  $s_1 = g$

(a) (*Yes, Stay*)

$$\sigma_g (p_g \pi^M - I) + \sigma_b (p_g \pi^M - I)$$

(b) (*Yes, Drop*)

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

(c) (*No, Stay*)

$$\sigma_g (p_g \pi^M - I) + \sigma_b (p_g \pi^M - I)$$

(d) (**No, Drop**)

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

2.  $s_1 = b$

(a) (*Yes, Stay*)

$$\sigma_g (p_b \pi^M - I) + \sigma_b (p_b \pi^M - I)$$

(b) (*Yes, Drop*)

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

(c) (*No, Stay*)

$$\sigma_g (p_b \pi^M - I) + \sigma_b (p_b \pi^M - I)$$

(d) (**No, Drop**)

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

3. ( ((*No, Drop*), (*No, Drop*)), ((*No, Drop*), (*No, Drop*))) is not an equilibrium as

$$\sigma_g \cdot 0 + \sigma_b \cdot 0 < \underbrace{\sigma_g (p_g \pi^M - I)}_{>0} + \underbrace{\sigma_b (p_g \pi^M - I)}_{>0}$$