Moral Hazard and the Internal Organization of Joint Research[1]

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Abstract

This paper analyzes the impact of agency problems on two entrepreneurs' choice whether to carry out a stand-alone or a joint project. A joint project can be conducted by a single or both entrepreneurs' research units, which are substitutes to a varying degree. Joint projects are chosen when they are of high value and/or for low degrees of duplication and complementarities between the units. Agency problems reduce the occurrence of joint projects as they have to be of higher value and/or exploit higher synergies. Joint projects making use of potential synergies are chosen too seldomly from a welfare standpoint.

Keywords: agency problems, joint projects, internal organization, synergies.

JEL codes: D23, D82, L24

1 Introduction

A number of research and development intensive industries, such as the software, biotechnology, the automobile, the electronics industry and many others have seen a strong increase in joint research and development projects. These joint projects may take the form for example of research joint ventures (RJVs), alliances, or bilateral agreements. Joint projects may cover various stages of the innovation process. Taking the pharmaceutical industry as an example, they may range from basic research, such as inventing new chemical entities (NCE) – that can then be used to develop medicaments having certain therapeutical indications – up to the development of new final products, such as drugs – including performing the necessary tests to get them approved by regulatory authorities (such as the *Food and Drug Administration,* FDA, in the US)[1]. The value created in these joint projects is often considerable and of high social interest. For this reason, there have been public programs set up by several governments and supranational authorities to support these projects. The EU for example does so within the "*European Framework Programs*". Out of the 363 million euro spent on "*Promotion of Innovation and Encouragement of SME*[2] *Participation in R&D*" within the 5th edition of these "*European Framework Programs*" from 1998 until 2000, the EU devoted 200 million euro to "*Joint innovation/SME activities*".

The relevance of this phenomenon explains the interest in studying the formation mechanisms, to analyze the rationale, possible failures, duration, and not least the impact on social welfare of joint projects.

Most of the recent literature that studies the underlying incentives to enter into joint projects as well as the conditions for their stability, concentrates on economic agents taking these decisions as if they were also responsible for carrying out the research. There is usually no separation between ownership and control. Therefore, possible conflicts between who takes the decision on whether to conduct a joint research, i.e. who has the formal control on this decision, and who might affect the outcome of the research, i.e. who has the real control, are not accounted for[3].

Our model departs from the traditional owner-manager view, by explicitly considering

[1] See Pammolli (1996) for a discussion on R&D in the pharmaceutical industry.

[2] Small and medium sized enterprises.

[3] For example, Espinosa and Macho-Stadler (2003) consider the endogenous formation of partnerships by firms in a double sided moral hazard context, i.e. each firm has to decide its level of production with which to contribute to the overall output of the partnership. Each owner has an incentive to free-ride on other owners by deciding how much (unobservable) effort to put into the overall production of the partnership. However, an owner-managers view on the problem is adopted, i.e. each owner is at the same time his own agent.

the impact of principal-agent relations on formation and internal organization of RJVs by allowing owners to decide whether to conduct a project alone or jointly, under both, the owner-manager and the principal-agent assumptions. Research units will be responsible of conducting the projects: their effort – alternatively observable or unobservable – determines in our model the probability of success of the projects. A joint project can be conducted by only one owner's research unit or both owners' research units (agents) together. In the latter case, our analysis will allow for these units to be substitutes to a varying degree. The model assesses the impact of agency problems on the owners' decisions to carry out a stand-alone or a joint project and whether to use possible synergies between research units.

To our best knowledge, there is one study of joint research that takes an explicit agency approach, Pastor and Sandonís (2002). The authors do not consider incentives to enter joint research projects: comparing cross-licensing agreements with research joint ventures in the presence of agency problems, joint research is the only means entrepreneurs have to conduct a given project. Therefore, staying alone is not an option and, contrary to our model, the analysis of the underlying incentives to form a research alliance is ruled out by assumption. The underlying assumption in their work is that each research unit's success is essential, both for the cross-licensing and for the research joint venture cases. By contrast, allowing for several degrees of substitution between research units (managers) involved in the joint project in order to reach a success, we are also able to characterize not only the decisions whether to join, but also the decision of how to do so as a function of these different degrees of substitution.

By accounting for possible substitutability, duplication, or complementarity of the agents' efforts in the functional form of the probability of success, we also depart from the team production literature[4] where the success of a task assigned to each agent is fundamental for the success of a given project. In our model, interactions between agents allow for potential synergies. However, results will show that synergies are not necessarily exploited in equilibrium. This is a consequence of a trade-off between the potential enhanced probability of success of the joint project for a given effort and the increased cost of providing it due to the optimal incentive compatible contracts to be offered to both research units.

Another aspect of our model consists of endogenizing the cost associated with conducting a research project. An often proposed argument to explain the forming a partnership is the ability that share fixed costs that would have to be incurred by each party separately otherwise. These fixed costs savings encompass research costs, savings on assets such as avoiding to replicate laboratories, as it is argued in Harrigan (1986). The relative benefits of enjoying a success, either alone or jointly, provides the rationale for private decisions whether

[4] See, for example, Holmström (1982) or Itoh (1991).

to run a joint or a stand-alone project. In our model the endogenized cost of conducting a research project can be considered to play an equivalent role as, in standard models, the fixed costs may play.

In order to concentrate on agency problems coming from moral hazard we abstract from several potentially interesting aspects like the fear of disclosing private know-how within a joint project, from market power considerations, and from the bargaining process underlying the determination of the sharing rule for the joint projects' benefits and costs. The potential trade-off between staying alone and joining when there is the fear of disclosing each firm's private know-how within a joint project has been considered by Pérez-Castrillo and Sandonís (1996). The abstraction from market power considerations (in the sense that the overall potential value of the market that projects can target does not depend on whether they join or not) suits situations where a success pays off a well defined value, which can be appropriated, totally or partially, by the author of this success. Examples are R&D projects leading to the patenting of the invention/innovation, or to the approval of a certain drug targeting a potential market. While the overall value of the market is kept fixed, we distinguish in our analysis between independent and common market projects. This separation is meant to capture both the cases where a stand-alone project is not facing a rival one, and the one where it does. Having conducted a successful stand-alone project will pay off a fixed value independent of whether the other entrepreneur succeeded if this projects targeted independent markets. As an example one could think of a market which is segmented due to regional regulatory constraints that do not allow an innovator to use a patent in another country than the one where the innovation was obtained. If the projects aim at a common market on the other hand, a success would have to be shared with the other entrepreneur if his project succeeds as well. Finally, concerning the bargaining, we assume an exogenous equal sharing of costs and benefits of the joint projects. This simplification is made in order to focus on the impact of agency problems on decision whether to join and how to join between equally important partners in the joint project.

Results will show that the decision to pursue joint projects is always taken between firms facing independent markets, no matter whether research units are affected by moral hazard behavior or not. However, for both, observable and unobservable efforts, under the common market assumption, firms start preferring staying alone as long as the value of the overall market to be targeted is not high enough, and/or if the degree of duplication is not too high. When entrepreneurs face agency problems, the value of the overall market to be targeted has to be higher than under observable efforts for entrepreneurs to pursue a joint project. The additional agency costs may induce the parties to stay alone even if they would otherwise have chosen to conduct the project jointly either with one or both units. Our results show that moral hazard, and thus, an increase of the component that inflates the cost of producing an innovation, *is not* a factor that drives firms to share it necessarily, i.e. to share a "fixed" cost, as it is usually considered. Given that the wage to be paid to the research management can be adjusted implementing the optimal wage contract associated with each case, firms may still decide to stay alone instead. In particular, the occurrence of joint projects where both units are kept is decreased systematically as higher complementarities are needed to sustain this configuration against either stand-alone or a joint project with one unit.

The analysis of the impacts of privately taken decisions over the social welfare, will show that conflicts arise under the moral hazard assumption where joint projects keeping both research units would be preferred socially, but privately firms prefer either to join keeping only one unit or not to join at all. Too few socially desirable joint projects exploiting synergies are observed.

The work is organized as follows. In section 2 we describe the setup of the model. Section 3 is devoted to the analysis of the owner-manager case. In section 4, we analyze the principal-agent alternative and compare results with the ones obtained in section 3. Section 5 concludes and discusses possible extensions of the model.

2 The Model

In this section, we describe the stand-alone configuration for both, projects targeting *independent markets* - or market segments - (I) and those targeting a *common market* (C), as well as the joint research configurations in which either one or both research units are kept. We first describe the characteristics of the projects, the utility of the agents' conducting them, the probability of success attached to the projects, and, finally, we introduce the notion of social welfare that is adopted in our study.

Entrepreneurs' projects Let two entrepreneurs pursue a project leading to an innovation targeting a potential market, the overall value of which is Δ. We can think of Δ as the value attached to licensing out, or patenting, an innovation to be used for the market. The market is exogenously segmented, into two parts, each of which is assumed to be of equal value $\frac{\Delta}{2}$.

As said, we distinguish the case in which entrepreneurs are either able to access one segment of the market, distinct from the segment accessed by the other, from the case in which each of them is able to access both segments of the market[5].

[5] The first situation, where entrepreneurs may be initially present in only one segment, can be interpreted as the case where only this "home" entrepreneur knows the regulatory framework of its country, which is a necessary condition to get approved for the innovation there, but not the other "foreign" entrepreneur. The

Given the segmentation of the market, if the project is conducted alone and each of the entrepreneurs can invest in a distinct segment of the available market, we will refer to the adoption of projects targeting independent markets, paying off $\frac{\Delta}{2}$ to each entrepreneur in the case of his success[6]. If each entrepreneur targets both segments, we will refer instead to projects targeting a common market, paying off Δ to a successful entrepreneur if he is the only one succeeding, or $\frac{\Delta}{2}$ to each of them if both are succeeding. It can be shown that our results do not change qualitatively if we assume that a success of both entrepreneurs in the common markets situation destroys value, i.e. if the value to be appropriated by each entrepreneur were smaller than $\frac{\Delta}{2}$.

Whenever instead, entrepreneurs decide to conduct a joint project, its success is assumed to lead to a success to be used in both segments of the market[7], paying off Δ.

In case of failure, a project always pays off zero.

Projects are assumed to be carried out by agents (research units, divisions, etc.) employed by the entrepreneurs. The agents affect the probability of success of the project they conduct through their chosen effort. We assume that each entrepreneur employs initially one agent (research unit, division, etc.). If the entrepreneurs decide to conduct the projects alone, we refer to a *stand-alone* case, either $(S|\, I)$ or $(S|\, C)$. If the entrepreneurs combine their assets for a joint project, we refer to either $(J1)$ or $(J2)$ depending on whether the entrepreneurs decide to keep each of their agents i, with $i = 1, 2$ to conduct the joint project, or only one of them. We are implicitly assuming that each agent has embedded the scientific knowledge/capability to conduct the project alone[8]. Any time the project is conducted jointly, we further assume that a new entity is founded. We refer to this entity as the *joint entity.* As mentioned already, entrepreneurs share the costs and the benefits of conducting the joint project equally.

Summarizing the assumptions made, we can write the different payoffs $R(\cdot)$ associated

second situation accounts for the case where both entrepreneurs have access to - or can develop for - both segments: this is possible either because they were initially present in both segments; or because each of them was initially present only in one segment, but they decide to conduct a joint project – and thus share the necessary knowledge for obtaining approval in their respective segments.

[6] This comes from the assumption of equally sized segments.

[7] The underlying assumption for this is that a project success in one segment can be easily translated into a success in the other segment: e.g. given the now common knowledge about the regulatory frameworks of each respective separate market, joining firms can tailor the project such that its scientific success ensures it to be used in both segments.

[8] As discussed before, this does not yet guarantee to access both segments of the market as there is still the regulatory hurdle to be taken.

with the stand-alone situation:

$$R_i(S|I) = \begin{cases} \frac{\triangle}{2} & with\ \Pr = p_i(S) \\ 0 & with\ \Pr = 1 - p_i(S), \end{cases} \tag{1}$$

$$R_i(S|C) = \begin{cases} \triangle & with\ \Pr = p_i(S)(1 - p_{-i}(S)) \\ \frac{\triangle}{2} & with\ \Pr = p_i(S)\, p_{-i}(S) \\ 0 & with\ \Pr = 1 - p_i(S), \end{cases} \tag{2}$$

where $p_i(S)$ and $p_{-i}(S)$ are the probabilities of success of firms i and $-i$, respectively. Similarly, we can write the payoffs associated with the joint cases:

$$R(J1) = \begin{cases} \triangle & with\ \Pr = p(J1) \\ 0 & with\ \Pr = 1 - p(J1), \end{cases} \tag{3}$$

$$R(J2) = \begin{cases} \triangle & with\ \Pr = p(J2) \\ 0 & with\ \Pr = 1 - p(J2), \end{cases} \tag{4}$$

where $p(J1)$ and $p(J2)$ are the probabilities of success of the joint project keeping one or two agents/research units, respectively.

Agents Agents affect the probability of success of the project they conduct through their effort. We consider both, the cases where the agents exert an observable, contractable effort e_i and where they exert a non observable, therefore not-contractable, effort. Exerting this effort e_i implies a disutility for the agent that is equal to $c_i(e_i) = \frac{1}{2}e_i^2$. For conducting the project, agents receive a transfer $t_i \geq 0$ from the entrepreneurs employing them. Both, entrepreneurs and agents are risk neutral, however, agents are protected by limited liability. We assume the agents' utility to be additively separable between effort and money,

$$U_i = u_i(t_i) - c_i(e_i) = t_i - \frac{1}{2}e_i^2. \tag{5}$$

In case of unobservable efforts, a contract, specifying a transfer to the agents cannot be made contingent on their exerted efforts, but only on the observable and verifiable success or failure of the project. In this case, the optimal contract requires the transfer to the agents made by the entrepreneurs employing them to be of the following type:

$$t_i(R) = \begin{cases} b_i & if\ success \\ 0 & if\ failure \end{cases} \tag{6}$$

In the joint cases $((J1), (J2))$ we will drop the index i while referring to the transfer agent(s) receive from the joint entity. If two agents are kept, we impose equal transfers to both agents[9]. In our model, giving equal wages for equal jobs, would emerge in equilibrium as the result of the minimization of the cost of implementing a given probability of success. This result is shown in appendix A.

[9]This may be due to legal constraints which oblige owners to pay comparable wages/transfers for compa-

Probability of success As already mentioned, agents affect the probability of success of the project by selecting which level of effort to exert. We define this probability as[10]:

$$\Pr(success) = \left(\sum_i e_i^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \leq 1. \tag{7}$$

Whenever only one agent is assigned to the project, this success probability collapses to either $\Pr(success\,|S)_i \equiv p(S)_i = e_i$ if each agent is employed by stand-alone entrepreneurs, or $\Pr(success\,|J1) \equiv p(J1) = e$ if the agent is employed by the joint entity. If both agents are kept in it, we have that $\Pr(success\,|J2) \equiv p(J2) = \left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$.

The parameter $\varepsilon \in [\underline{\varepsilon}, 1[$ determines the way agents' efforts interact with each other depending on the technology possibilities attached to a given project. We restrict the ε below in order to fulfill second order conditions of the entrepreneurs' optimization problems. We restrict it above as we want to keep the assumption that the project can be carried out by one agent alone. A value of ε which would tend to infinity would imply that agents' efforts are perfect complements, i.e. both agents' efforts would be needed to bring the project to a success. For this reason, and for tractability of the model, as we want to ensure the continuity of the maximization problems to be solved, we assume an upper bound for ε equal to 1. However, with or without this limit on the upper bound for ε, results are not affected.

Allowing for positive values of this parameter we can still consider situations where some projects may require agents to work together for the project to succeed. We can think about a project that lets the agents acquire information while exerting an effort together. This information needs to be shared between the two agents and it is crucial for making the project successful. Given this situation, a part of the effort of the agent working more than the other would be lost and would not contribute to the overall success of the project.

The technology parameter can also be negative. A negative ε accounts for the degree to which the agents' efforts are duplicates.

rable jobs. It could also be in the interest of the entrepreneurs to let their agents follow the project jointly in order not to loose part of the tacit knowledge that agents may acquire during the development of the project itself. Furthermore, giving an incentive contract to only one of the two agents will reduce this case to the $(J1)$ case.

[10] We will derive the optimal contracts not taking into account any restrictions on the parameters Δ and ε such that the probability of success is well defined, e.g. smaller than 1. If the unrestricted solution specified a probability level greater than one, entrepreneurs would not be able to increase the probability of success over the value of one by paying a higher transfer. They would, therefore, optimally specify an implemented effort and a transfer such that the probability is exactly equal to one. In the following analysis, we provide the unrestricted solutions for the optimally implemented efforts and transfers, however, it is always possible to verify that the results are unaltered by allowing for the restriction on the exogenous parameters to bind.

Finally, if $\varepsilon = 0$, agents' efforts are perfect substitutes. An example for this case is a project, which can be divided into two parts that may each partially contribute to the overall success of the project and which are assigned each to a different agent. Here no agent's effort overlaps the one of the other and the probability of success is determined by the overall amount of effort exerted by the two agents.

Social Welfare As we want to draw conclusions about the welfare impact of the entrepreneurs' organizational choice $((S|\cdot)$, $(J1)$, or $(J2))$, we now define the measure of social welfare $W(\cdot)$ we will use for each of the different environments we consider. Social welfare is assumed to consist of both the entrepreneurs' expected net profits and the agents' expected utility, equivalent therefore to the sum of the expected gross profits and the disutility of agents' efforts, i.e.:

$$W(S|\cdot) = \begin{cases} W(S|I) = (e_1 + e_2)\frac{\Delta}{2} - \frac{1}{2}e_1^2 - \frac{1}{2}e_2^2 \\ W(S|C) = (e_1 + e_2 - e_1 e_2)\Delta - \frac{1}{2}e_1^2 - \frac{1}{2}e_2^2, \end{cases} \tag{8}$$

$$W(J1) = e\Delta - \frac{1}{2}e^2, \text{ and} \tag{9}$$

$$W(J2) = \left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}\Delta - \frac{1}{2}e_1^2 - \frac{1}{2}e_2^2. \tag{10}$$

respectively for the stand-alone independent markets and common markets, and for the joint-one agent or two-agents cases.

The welfare induced by the privately taken decision is the result of both the specific configuration chosen for undertaking the project and the corresponding implemented probability of success.

In the stand-alone independent markets situation, segment i of the market will be served with probability e_i, creating a value of $\frac{\Delta}{2}$ in case of success of the project targeting that segment. In the stand-alone common market situation, at least one entrepreneur's success leads to serving the whole market, creating a value of Δ, which happens with probability $e_1 + e_2 - e_1 e_2$. In the joint project cases, $(J1)$ and $(J2)$, a success of the project allows the joint entity to create the value of Δ.

In any case, conducting a project comes at a cost: the agents' disutility of exerting an effort, $\frac{1}{2}e_i^2$ for each agent assigned to the project.

Timing Given that the target of stand-alone projects (independent markets or a common market) is exogenously taken ex ante, the actions of the different players can be summarized as follows:

1. Entrepreneurs simultaneously decide whether they want to invest in a joint or in a stand-alone project and how many agents to keep if they join.

2. Entrepreneurs offer contract(s) to the agent(s) involved in the project.

3. Agent(s) accept(s) or reject(s) the contract(s).

4. Agent(s) decide(s) on an effort level to be exerted.

5. The outcome is realized and the transfers are executed.

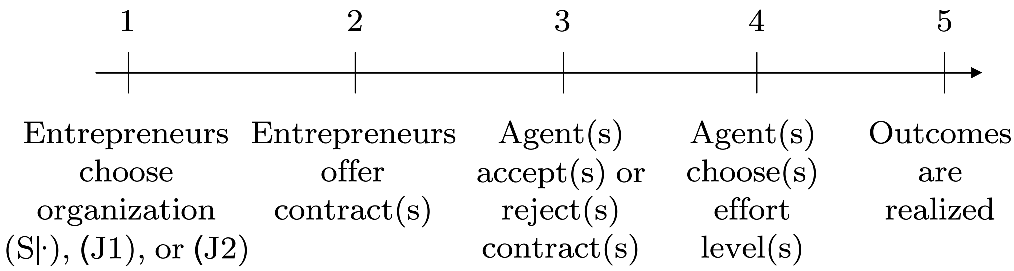

Figure 1: Timing

3 Benchmark: The owner-manager case

The goal of this section is to provide a benchmark analysis of the optimal organizations either when the agents' efforts are observable and therefore it is possible to make the transfer contingent to the exerted effort[11].

This benchmark will be compared to the parallel analysis when the efforts are not observable[12]. Comparisons will allow us to assess the impact of the separation between formal and real control – entrepreneurs have the power to decide whether to join, but agents affect the real outcome of that decision – on the privately chosen configuration and on the social welfare.

[11] Or, seeing it differently, when we have an owner-manager, i.e. an entrepreneur who could provide that effort alone, as if the he was also the manager. An example could be the case of a biotech firm funded by the biotechnician that is conducting the research himself. In this case of the analysis, we will adhere to the formulation that corresponds to the entrepreneur(s) having full control over their agent'(s) efforts. However, doing so, the alternative interpretation of the owner-manager case just given remains valid.

[12] This may happen any time the entrepreneur is not able to conduct the project alone, but needs the agent(s) and he is not able to judge whether the agent(s) behaved or not, but he can simply observe the result of his actions, either a success or a failure.

3.1 Stand-alone (S)

In this section we consider the case in which each entrepreneur conducts the project alone, employing one agent each. Here only the effort of this agent determines the probability of success of the project[13], i.e. $p_i(S) = e_i$. However, as outlined in the model setup, in our analysis, a success allows to access either one or both segments of a market depending on whether the project targeted a independent or a common market. For this reason, in the following analysis we distinguish between these two possible projects.

3.1.1 Independent Markets (I)

We first assume that the projects target independent market segments. This means that, when the entrepreneur is successful, he enjoys $\frac{\Delta}{2}$, regardless of the success or failure of the other entrepreneur. Each entrepreneur pays out a transfer that lets the agent break even.

Therefore, each entrepreneur solves the following maximization problem:

$$\max_{e_i} \Pi_i \left(S | \, I \right) = \max_{e_i} \left[e_i \frac{\Delta}{2} - t_i \right] \tag{11}$$

$$s.t. \qquad t_i - \frac{1}{2} e_i^2 \geq 0 \tag{IR}$$

$$t_i \geq 0. \tag{LL}$$

It is straightforward to show that the solution to this problem gives:

$$e_i^o \left(S | \, I \right) = e^o \left(S | \, I \right) = p^o \left(S | \, I \right) = \frac{\Delta}{2} \quad \text{and} \tag{12}$$

$$t_i^o \left(S | \, I \right) = t^o \left(S | \, I \right) = \frac{1}{2} \left(\frac{\Delta}{2} \right)^2, \tag{13}$$

where the superscript o denotes the profit-maximizing solution in the *observable* efforts case.

Following the notion of social welfare introduced in the general set up of the model, the expected welfare resulting from implementing the optimal probability in this case becomes:

$$W^o \left(S | \, I \right) = \left(\frac{\Delta}{2} \right)^2. \tag{14}$$

The implemented contract leads for each entrepreneur to an expected profit of:

$$\Pi^o \left(S | \, I \right) = \frac{1}{2} \left(\frac{\Delta}{2} \right)^2. \tag{15}$$

[13] Alternatively, the entrepreneur conducts the project alone facing the same disutility of effort as the agent would.

3.1.2 Common Market (C)

We now assume that entrepreneurs target a common market. According to our assumptions, if only one entrepreneur succeeds, he will be able to appropriate the whole value of the market, Δ; however, if both entrepreneurs succeed, they will have to share this value equally, appropriating each $\frac{\Delta}{2}$. Again, each entrepreneur pays out a transfer that lets the agent break even.

Each entrepreneur, thus, solves the following maximization problem:

$$\max_{e_i} \Pi_i \left(S \middle| C \right) = \max_{e_i} \left[e_i \left((1 - e_{-i}) \Delta + e_{-i} \frac{\Delta}{2} \right) - t_i \right] \tag{16}$$

$$s.t. \qquad t_i - \frac{1}{2} e_i^2 \geq 0 \tag{IR}$$

$$t_i \geq 0, \tag{LL}$$

the solution to which gives the equilibrium efforts and transfers:

$$e_i^o \left(S \middle| C \right) = e^o \left(S \middle| C \right) = p^o \left(S \middle| C \right) = \frac{2\Delta}{\Delta + 2} \quad \text{and} \tag{17}$$

$$t_i^o \left(S \middle| C \right) = t^o \left(S \middle| C \right) = \frac{1}{2} \left(\frac{2\Delta}{\Delta + 2} \right)^2, \tag{18}$$

where, again, the superscript o denotes the profit-maximizing solution in the *observable* efforts case.

The expected welfare associated with this solution is instead:

$$W^o \left(S \middle| C \right) = \left(\frac{2\Delta}{\Delta + 2} \right)^2. \tag{19}$$

The expected net profit for each entrepreneur is:

$$\Pi^o \left(S \middle| C \right) = \frac{1}{2} \left(\frac{2\Delta}{\Delta + 2} \right)^2. \tag{20}$$

3.2 Joint research

In this subsection, we assume that entrepreneurs decide to pursue the research project jointly. In this world, the project is targeting the whole (common) market.

When two entrepreneurs invest into a joint project, as assumed, they form a new entity and choose either to let one agent run the project alone or to let their agents work together. We also assumed that the joint entity offers a transfer to their agent(s), and that entrepreneurs share equally the cost of the transfer(s), as well as the payoff of the project.

3.2.1 Joint-one agent $(J1)$

In the $(J1)$ case, only the effort of one agent determines the probability of success of the joint project so that $p(J1) = e$. As assumed, in case of success, both segments of the market are covered, giving rise to a value of Δ.

Therefore, the joint entity's maximization problem is:

$$\max_{e} \Pi(J1) = \max_{e} [e\Delta - t] \tag{21}$$

$$s.t. \qquad t - \frac{1}{2}e^2 \geq 0 \tag{IR}$$

$$t \geq 0 \tag{LL}$$

As in the previous subsection we can derive the following solution to this problem:

$$e^o(J1) = p^o(J1) = \Delta, \tag{22}$$

$$t^o(J1) = \frac{\Delta^2}{2}. \tag{23}$$

The expected welfare associated with this case is:

$$W^o(J1) = \frac{\Delta^2}{2}, \tag{24}$$

and each entrepreneur/principal expects a profit equal to:

$$\Pi^o(J1) = \frac{1}{2}\left(\frac{\Delta^2}{2}\right). \tag{25}$$

3.2.2 Joint-two agents $(J2)$

In the $(J2)$ case, the probability of success becomes a function of both agents' efforts so that $p(J2) = \left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$. As cost minimization requires that the joint entity proposes to each agent exactly the same contract[14], we show results here as if the constraint was imposed from the beginning. Again it is assumed that in case of success both segments of the market are covered, giving rise to a value of Δ.

Therefore, given that we take $t_1 = t_2 = t$, the joint entity's maximization problem is:

$$\max_{t} \Pi(J2) = \max_{t} \left[\left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} \Delta - 2t\right] \tag{26}$$

$$s.t. \qquad t - \frac{1}{2}e_i^2 \geq 0 \qquad \forall i \tag{IR}$$

$$t \geq 0 \qquad \forall i. \tag{LL}$$

[14]The proof is given in appendix A.

This problem leads to the following results:

$$e_i^o(J2) = e^o(J2) = 2^{\frac{\varepsilon}{1-\varepsilon}}\Delta, \quad (27)$$

$$p^o(J2) = 2^{\frac{1+\varepsilon}{1-\varepsilon}}\Delta, \quad (28)$$

$$t^o(J2) = 2^{\frac{3\varepsilon-1}{1-\varepsilon}}\Delta^2. \quad (29)$$

For the $(J2)$ case, we get an expected welfare equal to:

$$W^o(J2) = 2^{\frac{2\varepsilon}{1-\varepsilon}}\Delta^2, \quad (30)$$

and a per entrepreneur expected profit of:

$$\Pi^o(J2) = \frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\Delta^2\right). \quad (31)$$

3.3 Optimal organizational form for observable efforts

We are now able to draw some conclusions about the privately (and socially, as they coincide in this case) chosen organizations when efforts are observable. The following table summarizes the results found above:

Configurations	$(S\vert I)$	$(S\vert C)$	$(J1)$	$(J2)$
$\Pi^o(\cdot) = \frac{1}{2}W^o(\cdot)$	$\frac{1}{2}\left(\frac{\Delta}{2}\right)^2$	$\frac{1}{2}\left(\frac{2\Delta}{\Delta+2}\right)^2$	$\left(\frac{\Delta}{2}\right)^2$	$\frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\Delta^2\right)$
$p^o(\cdot)$	$\frac{\Delta}{2}$	$\frac{2\Delta}{\Delta+2}$	Δ	$2^{\frac{1+\varepsilon}{1-\varepsilon}}\Delta$

The comparison between the different levels of profits (and social welfare) lead to the following proposition.

Proposition 1 *Under the owner-manager assumption (alternatively: for observable efforts),*

(*i*) *in the independent markets case, entrepreneurs always invest jointly,*

- (*a*) *for* $\varepsilon \in]-1, 1[$*, they keep both agents,*
- (*b*) *for* $\varepsilon \notin]-1, 1[$*, they keep one agent,*

(*ii*) *in the common markets case,*

- (*a*) *for* $\varepsilon \in]-1, 1[$*, entrepreneurs invest jointly and keep both agents if*

$$\Delta > 2^{-\frac{2\varepsilon-1}{1-\varepsilon}} - 2,$$

and invest in a stand-alone project otherwise, *(b) for $\varepsilon \notin]-1, 1[$, entrepreneurs invest jointly and keep one agent if*

$$\Delta > 2\sqrt{2} - 2,$$

and invest in a stand-alone project otherwise.

In our results we do not distinguish between privately and socially preferred configurations, as they coincide under observability of the agents' efforts[15].

When entrepreneurs are facing a independent markets world, there are only effects on the expected cost side: the cost of implementing the optimal effort is possible to be shared in $(J1)$, or synergies are exploited in $(J2)$. There is no effect on the expected payoffs side when implementing *one and the same* level of the probability of success. This explains the decision to always join under the independent markets assumption.

In contrast, when entrepreneurs face a common market, we have to distinguish between two cases. Entrepreneurs join, opting for $(J2)$, either as long as the agents' efforts are complements, for $\varepsilon \in]0, 1[$, no matter which is the overall value of the market, or when the value of the market is high enough in presence of agents' efforts which are slight duplicates $]-1, 0[$. The less the agents' efforts duplicate each other, the lower is the value of the market necessary for them to join. For higher degrees of duplication $(J1)$ is chosen over $(S|\, C)$ as long as the overall value of the market is high enough.

Results *for the common market case* are shown graphically in figure 2.

The $\Pi^o_{(S),(J2)}$ is the indifference curve of relevant combinations of Δ and ε above which $(J2)$ is preferred to $(S|\, C)$; similarly, $\Pi^o_{(S),(J1)}$ is the indifference curve for the relevant combinations of the same parameters above which profits in $(J1)$ are higher than the ones in $(S|\, C)$; and, finally, for the relevant parameters combinations the indifference curve $\Pi^o_{(J1),(J2)}$ separates the left(right) area where profits in $(J1)$ are higher(lower) than in $(J2)$. Therefore, these three curves depict three regions: area $(S|\, C)^o$, $(J1)^o$, and $(J2)^o$, where firms prefer $(S|\, C)$, $(J1)$, and $(J2)$, respectively.

Note that we derived the optimal contracts not taking into account any restrictions on the parameters Δ and ε such that the associated probabilities of success are well defined, e.g. smaller than 1. For example, for $\Delta = 2$, the unrestricted solution for the stand-alone case specifies an effort level $e^o_i(S|\, C) = 1$ and, thus, implements a probability of success of $p^o_i(S|\, C) = 1$. For $\Delta > 2$, the unrestricted solution would specify an effort

[15] If the innovation led to the commercialization of a product, then consumers' surplus considerations could make a difference between what would be privately chosen from what would be socially desirable. In Fabrizi and Lippert (2004) similar considerations are taken into account as a merging decision is analyzed together with its impact on the overall social welfare that includes consumers' surplus.

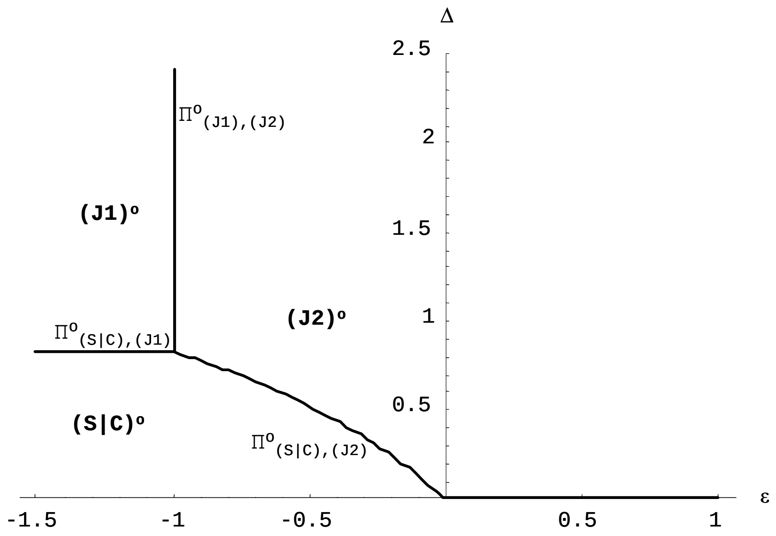

Figure 2: Optimal configurations for observable efforts.

level greater than 1. However, entrepreneurs cannot increase the probability of success by implementing an higher effort, i.e. even by paying higher transfers. The restricted solution requires implemented efforts and transfers such that $e_i^o(S|C) = 1$ and $t_i^o(S|C) = \frac{1}{2}$. In the same spirit, the restricted contracts can be found for the stand-alone configuration in the independent markets case, as well as for the joint configurations with one or two agents: for $\Delta > 2$, $e_i^o(S|I) = 1$ and $t_i^o(S|I) = \frac{1}{2}$, for $\Delta > 1$, $e^o(J1) = 1$ and $t^o(J1) = \frac{1}{2}$, and for $\Delta > 2^{-\frac{1+\varepsilon}{1-\varepsilon}}$, $e_i^o(J2) = 2^{-\frac{1}{1-\varepsilon}}$ and $t_i^o(J2) = \frac{1}{2}2^{-\frac{1}{1-\varepsilon}}$. Note that figure 2 takes into account both, the unrestricted and the restricted contracts, enabling us to make the same profit and welfare comparisons for $\Delta > \min\left\{1, 2^{-\frac{1+\varepsilon}{1-\varepsilon}}\right\}$, too. The reason for this is that indifference curves depicted would not change when taking the restricted solutions: those between the stand-alone and the joint configurations are below $\Delta = \min\left\{1, 2^{-\frac{1+\varepsilon}{1-\varepsilon}}\right\}$ and the one between the two joint configurations is independent of Δ. A similar reasoning can be replicated for the unobservable case.

To give an intuition about how firms take their decision between staying alone or pursuing a joint project in the common markets case, we need to distinguish between two possible effects: one coming from the differences in expected payoffs and another from differences in expected costs, associated with one configuration instead of the other.

First, the expected payoffs associated with $(S|C)$ and $(J1)$ for *one and the same* probability of success are respectively $p(1-p)\Delta + p^2\frac{\Delta}{2} = p(2-p)\frac{\Delta}{2}$ and $p\frac{\Delta}{2}$. In other words, the expected payoff for this probability is higher in $(S|C)$ than in $(J1)$. Second, for *one and the same* probability of success the costs in $(S|C)$ and $(J1)$ are respectively $\frac{p^2}{2}$ and $\frac{1}{2}\frac{p^2}{2}$.

This means that it is more costly in $(S|\,C)$ than in $(J1)$ to implement *one and the same* probability of success. The enhanced payoffs that choosing $(S|\,C)$ against $(J1)$ ensures, conflict with the higher costs associated to this choice. Enhanced payoffs and cost savings go in opposite directions, and which of them outweighs the other depends on the level of a given implemented probability.

The optimal implemented probabilities associated with $(J1)$ and $(S|\,C)$ are *not the same*: in $(J1)$ they are systematically higher than in $(S|\,C)$ and they are both increasing functions of Δ. In addition, an increase in Δ lets the optimal probability in $(J1)$ increase more than the one in $(S|\,C)$. The optimal profits themselves are strictly increasing functions of Δ and the relative impact of an increase in Δ makes the enhanced payoffs advantage being relatively less important as compared to the cost savings, when choosing $(S|\,C)$ against $(J1)$. There exists a threshold value for Δ above which $(J1)$ is systematically preferred to $(S|\,C)$, $\Delta > 2\sqrt{2}-2$.

A similar reasoning could be replicated in the comparison between $(S|\,C)$ and $(J2)$ with the additional relative advantage of joining whenever ε allows for bigger and bigger synergies: $\forall\varepsilon \in \,]-1,1[$, the cutoff value of Δ for $(J2)$ is smaller than the one for $(J1)$: $2^{-\frac{2\varepsilon-1}{1-\varepsilon}} - 2 < 2\sqrt{2} - 2$.

As observed, the optimal implemented probability of success is lower in the stand-alone than in the joint cases. This is because potential expected payoffs associated with succeeding alone are maximized for intermediate probabilities of success. Increasing the probability of success further puts more weight on the shared market component in the expected payoffs, which is common to both $(S|\,C)$ and $(J\cdot)$, as compared to the component associated with succeeding alone, which is specific to $(S|\,C)$.

4 The principal-agent case

In this section we consider the entrepreneurs' decisions with regard to the organizational choice and the optimal contracts under the assumption that agents efforts are not observable. Contracts cannot be made contingent on the level of these efforts, but only on the verifiable success or failure of the project.

Within this context, we replicate the analysis made in the previous section in order to derive the optimal contracts and the internal organization chosen by the entrepreneurs, as functions of Δ and ε in a similar way as we did for the observable efforts case. We then compute the expected welfare induced by the privately optimal internal organizations.

Results will allow us to discuss the impact of agency problems on the decisions of whether to enter a joint project. In contrast to the observable efforts case, social welfare does not coincide anymore with the overall expected profits in the economy. Therefore, a conflict can potentially arise between the privately chosen organizations and the socially preferred ones. We will characterize this conflict as a function of Δ and ε.

4.1 Stand-alone (S)

As before, we distinguish between the independent and common market projects when we derive optimal contracts. Again, if entrepreneurs decide to invest in a stand-alone project, its probability of success is $p_i(S) = e_i$.

Efforts are not observable, so that entrepreneurs have to provide their agents with incentives to let them exert an effort. In this case, agent i gets a positive bonus, b_i, in case of success of the project he conducts and zero otherwise (as it has been discussed in the general setup of the model). Given this type of contract, agent i's maximization program is:

$$\max_{e_i} U_i = \max_{e_i} \left[e_i b_i - \frac{1}{2} e_i^2 \right], \tag{32}$$

the solution to which gives the incentive compatibility constraint (IC):

$$e_i = b_i. \tag{IC}$$

Entrepreneurs will take this constraint into account when they decide about the contract to offer to their agents. Notice that, no matter whether the markets are independent or common, the incentive compatibility constraint to be taken into account by the entrepreneurs stays the same.

4.1.1 Independent Markets (I)

Each entrepreneur solves for the following problem:

$$\max_{b_i} \Pi_i \left(S | \, I \right) = \max_{b_i} \left[e_i \frac{\Delta}{2} - e_i b_i \right] \tag{33}$$

$$s.t. \quad e_i = b_i \tag{IC}$$

$$e_i b_i - \frac{1}{2} e_i^2 \geq 0 \tag{IR}$$

As a solution, the bonus received by either agent is the same, and, given the (IC), corresponds to the implemented probability of success:

$$b_i^u \left(S | \, I \right) = b^u \left(S | \, I \right) = \frac{\Delta}{4} = p^u \left(S | \, I \right). \tag{34}$$

The superscript u denotes the profit-maximizing solution in the *unobservable* efforts case.

Note that the induced probability of success is *half* the one that an owner-manager would have chosen.

Each entrepreneur's expected profit is:

$$\Pi^u (S|\, I) = \left(\frac{\Delta}{4}\right)^2. \tag{35}$$

The expected welfare that results from the implementation of this contract is:

$$W^u (S|\, I) = 3\left(\frac{\Delta}{4}\right)^2. \tag{36}$$

4.1.2 Common Market (C)

Each entrepreneur, solves the following maximization problem:

$$\max_{b_i} \Pi_i (S|\, C) = \max_{b_i} \left[e_i \left((1 - e_{-i}) \Delta + e_{-i} \frac{\Delta}{2} \right) - e_i b_i \right] \tag{37}$$

$$s.t. \qquad e_i = b_i \tag{IC}$$

$$e_i b_i - \frac{1}{2} e_i^2 \geq 0. \tag{IR}$$

In equilibrium, the implemented efforts and the bonuses chosen are:

$$e_i^u (S|\, C) = e^u (S|\, C) = p^u (S|\, C) = \frac{2\Delta}{\Delta + 4} \quad \text{and} \tag{38}$$

$$b_i^u (S|\, C) = b^u (S|\, C) = \frac{2\Delta}{\Delta + 4}, \tag{39}$$

where, again, the superscript u denotes the profit-maximizing solution in the *unobservable* efforts case. Note that the implemented probability of success is *more than half* the one chosen under observable efforts. This is due to a strategic effect between the owners.

This leads to an expected net profit for each entrepreneur of:

$$\Pi^u (S|\, C) = \left(\frac{2\Delta}{\Delta + 4}\right)^2. \tag{40}$$

The expected welfare associated with this solution is:

$$W^u (S|\, C) = 3\left(\frac{2\Delta}{\Delta + 4}\right)^2. \tag{41}$$

4.2 Joint-one agent $(J1)$

We know that, if entrepreneurs decide to invest in a joint-one agent project, its success probability is $p(J1) = e$. Again, entrepreneurs face a (IC) constraint that comes from the agent's utility maximization problem corresponding to the one of the stand-alone case above.

The incentive compatibility constraint is therefore the same where the index i has been dropped:

$$e = b. \tag{42}$$

Thus, the joint entity solves:

$$\max_b \Pi(J1) = \max_b [e\Delta - eb] \tag{43}$$

$$s.t. \quad e = b \tag{IC}$$

$$eb - \frac{1}{2}e^2 \geq 0, \tag{IR}$$

which gives the following results:

$$b^u(J1) = \frac{\Delta}{2} \quad \text{and} \tag{44}$$

$$e^u(J1) = p^u(J1) = \frac{\Delta}{2} = \frac{p^o(J1)}{2}. \tag{45}$$

Here the induced probability of effort is *half* the one that an owner-manager would have chosen.

Given the equal sharing rule between entrepreneurs after joining forces, the implemented effort and chosen bonus determines a per entrepreneur profit of:

$$E\Pi^u(J1) = \frac{1}{2}\left(\frac{\Delta}{2}\right)^2. \tag{46}$$

The expected welfare that results from the implementation of this contract is:

$$W^u(J1) = \frac{3}{2}\left(\frac{\Delta}{2}\right)^2. \tag{47}$$

4.3 Joint-two agents $(J2)$

If entrepreneurs decide to invest in a joint-two agents project, the probability of success is a function of both agents' efforts, $p(J2) = \left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$. Entrepreneurs face again the (IC) constraint, one for each of their employed agents, and, again, share equally the bonuses to be paid to them, as well as the potential value coming from the joint project.

Each agent maximizes his own utility w.r.t. his own effort taking as given the one of the other agent. The first order conditions of these problems determine each agent's reaction function. When taken together, the reaction functions lead to the (IC) constraint to be taken into account by the joint entity when solving for the optimal implemented contract to be offered to the agents.

The agents' maximization problems are:

$$\max_{e_1} U_1 = \max_{e_1} \left[\left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} b - \frac{1}{2} e_1^2 \right] \quad \text{and} \tag{48}$$

$$\max_{e_2} U_2 = \max_{e_2} \left[\left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} b - \frac{1}{2} e_2^2 \right], \tag{49}$$

the first order conditions of which are:

$$e_1^{-\varepsilon} \left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon} \right)^{\frac{\varepsilon}{1-\varepsilon}} b - e_1 = 0, \tag{50}$$

$$e_2^{-\varepsilon} \left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon} \right)^{\frac{\varepsilon}{1-\varepsilon}} b - e_2 = 0. \tag{51}$$

The Nash solution to the agents' problems gives the (IC) constraint:

$$e_1 (J2) = e_2 (J2) = e (J2) = 2^{\frac{\varepsilon}{1-\varepsilon}} b. \tag{IC}$$

The probability of success for the joint-two agents case, compatible with the (IC) constraint, can be rewritten as:

$$p(J2) = 2^{\frac{1+\varepsilon}{1-\varepsilon}} b, \tag{52}$$

and each agent's (IR) constraint as:

$$p(J2)b - \frac{1}{2} \left[e (J2) \right]^2 \geq 0. \tag{53}$$

The joint entity solves, therefore, for:

$$\max_b \Pi (J2) = \max_b \left[p(J2) (\Delta - 2b) \right] \tag{54}$$

$$s.t. \quad e (J2) = 2^{\frac{\varepsilon}{1-\varepsilon}} b \qquad \forall i \tag{IC}$$

$$p(J2)b - \frac{1}{2} \left[e (J2) \right]^2 \geq 0 \qquad \forall i \tag{IR}$$

The optimal bonus each agent receives is:

$$b^u (J2) = \frac{\Delta}{4} \tag{55}$$

and, as a consequence, the implemented efforts and probability of success are:

$$e^u (J2) = 2^{\frac{\varepsilon}{1-\varepsilon}} \frac{\Delta}{4} \quad \text{and} \tag{56}$$

$$p^u (J2) = 2^{\frac{1+\varepsilon}{1-\varepsilon}} \frac{\Delta}{4} = \frac{p^o (J2)}{4}. \tag{57}$$

The probability induced by keeping two agents is equal to one fourth the one chosen by owners-managers. We should, thus, expect $(J2)$ to be chosen less often than in the owner-manager's case.

Given the implemented efforts and bonuses each entrepreneur expects a profit equal to:

$$\Pi^{u}(J2)=\frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^{2}\right), \tag{58}$$

and the induced expected welfare equals:

$$W^{u}(J2)=\frac{7}{4}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^{2}\right). \tag{59}$$

4.4 Optimal organizational form for unobservable efforts

We are now able to draw some conclusions about the privately chosen organizations under the unobservable efforts assumption, and about their impact on social welfare. Results obtained in the previous sections are summarized in the following table:

Configurations	$(S\|I)$	$(S\|C)$	$(J1)$	$(J2)$
$\Pi^{u}(\cdot)$	$\left(\frac{\Delta}{4}\right)^{2}$	$\left(\frac{2\Delta}{\Delta+4}\right)^{2}$	$\frac{1}{2}\left(\frac{\Delta}{2}\right)^{2}$	$\frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^{2}\right)$
$W^{u}(\cdot)$	$3\left(\frac{\Delta}{4}\right)^{2}$	$3\left(\frac{2\Delta}{\Delta+4}\right)^{2}$	$\frac{3}{2}\left(\frac{\Delta}{2}\right)^{2}$	$\frac{7}{4}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^{2}\right)$
$p^{u}(\cdot)$	$\frac{\Delta}{4}$	$\frac{2\Delta}{\Delta+4}$	$\frac{\Delta}{2}$	$2^{\frac{2\varepsilon}{1-\varepsilon}}\frac{\Delta}{2}$

A comparison of the different outcomes, leads to the following propositions:

Proposition 2 *Under the principal-agents assumption, (alternatively: for unobservable efforts),*

(i) in the independent markets case, entrepreneurs always invest jointly,

(a) for $\varepsilon\in\,]0,1[$ they keep both agents and

(b) for $\varepsilon\notin\,]0,1[$ they keep one agent;

(ii) in the common markets case,

(a) for $\varepsilon\in\,]0,1[$, entrepreneurs invest jointly and keep both agents if

$$\Delta>4\left(2^{\frac{-\varepsilon}{1-\varepsilon}}\sqrt{2}-1\right),$$

and invest in a stand-alone project otherwise,

(b) *for* $\varepsilon \notin]0,1[$, *entrepreneurs invest jointly and keep one agent if*

$$\Delta > 4\left(\sqrt{2}-1\right),$$

and invest in a stand-alone project otherwise.

Proposition 3 *Under the principal-agents assumption, (alternatively: for unobservable efforts),*

(i) *in the independent markets case,*

- (a) *the private decision to invest jointly is welfare improving as compared to staying alone;*
- (b) *however, there exists a conflict between the privately chosen and the socially desirable joint configurations: for* $\varepsilon \in]-0.125, 0[$ $(J1)$ *is privately chosen whereas* $(J2)$ *would have been socially preferable;*

(ii) *in the common markets case,*

- (a) *if the joint configuration is chosen, this is always welfare improving as compared to staying alone;*
- (b) *however, two different types of conflicts between the privately chosen and the socially desirable configurations may arise:*
  - *b1 for* $\varepsilon \in]-0.125, 0[$ *and* $\Delta > 4\left(\sqrt{2}-1\right)$, $(J1)$ *is privately chosen whereas* $(J2)$ *would have been socially preferable;*
  - *b2 for* $\Delta \in \left]0, 4\left(\sqrt{2}-1\right)\right[\cap \left]4\left(2^{\frac{1-2\varepsilon}{1-\varepsilon}}\sqrt{\frac{3}{7}}-1\right), 4\left(2^{\frac{-\varepsilon}{1-\varepsilon}}\sqrt{2}-1\right)\right[$, $(S|C)$ *is privately chosen whereas* $(J2)$ *would have been socially preferable.*

Notice that now in our results we need to distinguish between privately and socially preferred configurations, as they do not coincide anymore due to the unobservability of the agents' efforts.

As before, when entrepreneurs are facing a independent markets world, there are only effects on the expected cost side. Even though the magnitude of these costs is changed, due to the incentive compatible contracts to be offered to the agents, their relative difference makes still entrepreneurs prefer to join over staying alone. Therefore, all comments made in the observable efforts case apply here as well. In addition, we can observe that the privately chosen joint configurations are welfare improving over staying alone. However, a conflict between privately chosen and socially desirable configurations arises here. The joint configuration where two agents are kept is chosen too seldomly as compared to what would have been socially desirable. To few joint projects exploiting potential synergies are observed.

In a similar way, when entrepreneurs face a common market, the two effects identified in the observable efforts case appear again. In the interval $\varepsilon \in]0,1[$, i.e. when agents' efforts are complements, the option $(J2)$ is always preferred to $(J1)$, no matter which is the value of the market. In this case, entrepreneurs join as before, opting for $(J2)$ over $(S|\,C)$, but only for a restricted range of the parameters Δ and ε : the higher the degree of complementarity between agents' efforts, the lower the level of the value of the market necessary to sustain the choice of $(J2)$; above a given threshold for this agents' complementarity, no matter which is the value of the market, the option $(J2)$ is always sustained. When $\varepsilon \notin]0,1[$ if the value of the market is high enough, i.e. $\Delta > 4\left(\sqrt{2}-1\right)$, $(J1)$ is preferred to $(S|\,C)$. A similar choice was taken under the observable efforts assumption, but for a smaller range of ε and a lower level of Δ, remember that $(J1)$ prevailed over $(S|\,C)$ for $\varepsilon \notin]-1,1[$ and $\Delta > 2\left(\sqrt{2}-1\right)$. Concerning the impact of privately taken decision, we can observe that here as well, as for the independent markets case, if a joint configuration is privately chosen this is also welfare improving over staying alone. However, too few joint projects with two agents are chosen as compared to what would be socially desirable. For high values of the market entrepreneurs choose joint project where only one agent is kept, and for low values of the market they choose instead a stand-alone project.

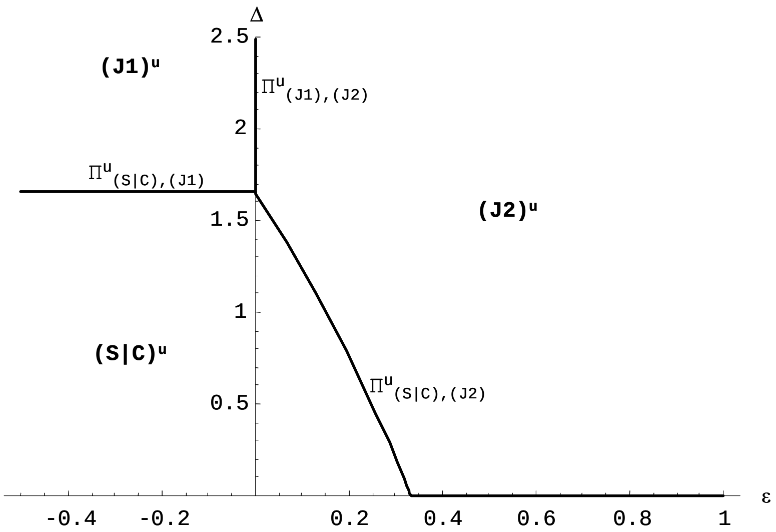

Figure 3: Privately chosen configurations for unobservable efforts.

Note that, as for the observable efforts case, we derived the optimal contracts not taking into account any restrictions on the parameters Δ and ε such that the associated probabilities of success are well defined, e.g. smaller than 1. As before, it can be shown that the unrestricted and restricted contracts can be both summarized in the same figure, as done in figure 3, where results for the common market case can be shown graphically.

In this figure, $\Pi^u_{(S),(J2)}$, $\Pi^u_{(S),(J1)}$ and $\Pi^u_{(J1),(J2)}$ represent the relevant indifference curves as the ones under the observable efforts case. The superscript u refers to the unobservable case we are describing now. As before, these three curves depict three regions: one, where firms prefer $(S|\,C)$, one, in which firms prefer $(J1)$, and, one, where the $(J2)$ configuration is chosen.

In addition, as we want to describe the possible conflicts between the privately and the socially preferred configurations, we draw figure 4, where the indifference curves for the welfare comparisons are added. The curves $W^u_{(S),(J2)}$, $W^u_{(S),(J1)}$ and $W^u_{(J1),(J2)}$ divide the regions where respectively staying alone is preferred to joining with two agents, or with one, or joining with one is preferred to joining with two agents.

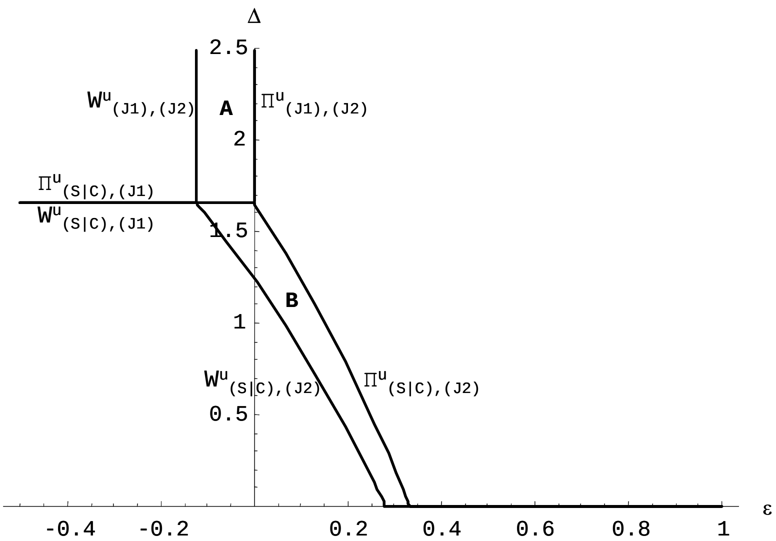

Figure 4: Privately and socially preferred configurations for unobservable efforts.

In figure 4, for the comparisons of interest, we have highlighted the two areas of conflict described above. In area A entrepreneurs choose to join with one agent, while joining with two would have been socially preferred. This happens for high enough values of the market, i.e. $\Delta > 4\left(\sqrt{2}-1\right)$, and low levels of agents' efforts duplication, i.e. $\varepsilon \in \left]-0.125, 0\right[$. This conflict is of the same nature as the one observed under the independent market assumption. It derives from the fact that joining with two agents is more costly privately than socially as entrepreneurs face a higher costs that comes from the informational rent to be paid to agents. This explains why joint projects where two agents are kept are observed more seldomly than socially desired. In area B entrepreneurs pursue a stand-alone project, while, again, a joint project where both agents were kept would have been socially preferred instead. This happens for values of the markets smaller than for area A, combined with efforts that are slight duplicates up to slight complements. Starting from the value of the market that makes both the society and the entrepreneurs indifferent between staying alone and joining with one agent, the lower the values of the market, the higher the efforts' complementarities have to be in order to observe a conflict of this nature.

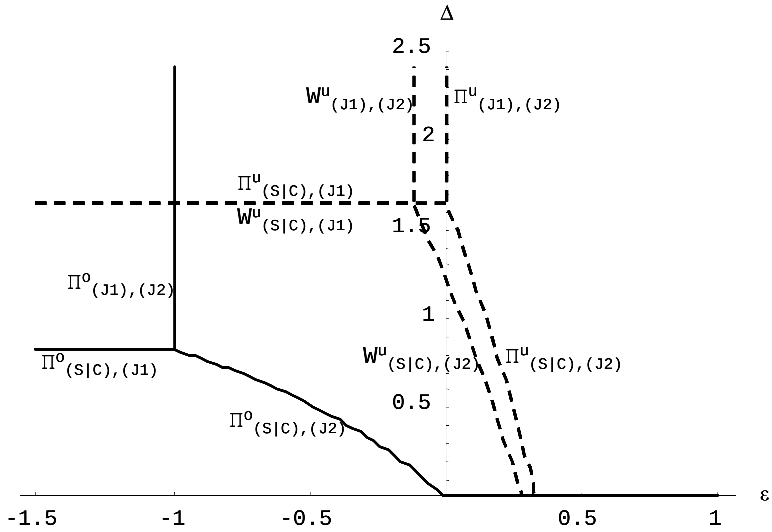

Figure 5: Comparison between privately and socially preferred configurations for observable and unobservable efforts.

Figure 5 compares results obtained in this section with the ones obtained under the observable efforts case. The solid lines depict the private (and social, as they coincide) indifference curves for the observable efforts case, whereas the dashed lines depict those for the unobservable one. The graph shows that there are two implications of moral hazard in our model. On the one hand, the value of the market necessary to make the option of joining with one agent preferred over staying alone shift upwards: it is higher under the moral hazard assumption than without moral hazard. Staying alone is now preferred to joining with either one or two agents more often. On the other hand, joining with two agents is chosen only for higher complementarities, even when the value of the market may be relatively low, or for low complementarities provided that the value of the market is high enough. The reason for this shift is that a low level of the market should be compensated by higher complementarities than under the observable efforts assumption for letting the option $(J2)$ be preferred over staying alone. The net effect over the joint one-agent configuration is therefore ambiguous. This is because it is true that only a higher value of the market makes entrepreneurs eager to join with one agent now, but at the same time, thanks to the shift on the right of the indifference curve against the joint option with two agents, this becomes possible in combination with a larger range of agents' efforts substitutability than before.

Introducing moral hazard changes the cost side of the model: It makes the implementation of *one and the same* probability of success in both, $(S|\,C)$ and $(J1)$ twice as expensive: the cost of implementing p in $(S|\,C)$ is now $bp = p^2$ and the cost of implementing p in $(J1)$ is $\frac{1}{2}bp = \frac{1}{2}p^2$. The difference in these costs is also twice as big. This effect would per se speak in favor of observing more often a sharing of the costs under $(J1)$. However, under moral hazard the optimal implemented probability of success are, as under the observable efforts case, not the same. In $(J1)$ the optimal implemented probability of success is one half of that in the situation with observable efforts, while the one in $(S|\,C)$ is more than one half the one under observable efforts, even though reduced. This difference in the change of the implemented probabilities, makes the relative cost savings associated to $(J1)$ as compared to the enhanced expected payoffs of staying alone, not as high as before. The option $(S|\,C)$ is now preferred more often over $(J1)$. In addition, even though the cost savings advantage is partially lost, the option $(J1)$ is now preferred more easily against the option $(J2)$ - because of the exacerbated cost induced by the moral hazard behavior which makes it more costly to join with two agents, joining with two agents is chosen only for higher levels of complementarity than before. Therefore, the overall net effect of moral hazard on $(J1)$, as it has been pointed out, is ambiguous.

5 Conclusion

In this paper, we have introduced agency problems into the RJV formation literature, departing from the traditional owner-managers view. This way, we have given an alternative rationale for joint research projects through optimal implemented contracts. The model proposed has explained the difference in the internal organizations of joint projects between the situations in which there are owner-managers as compared to when there is a principal-agent relation between the owner(s) and the agents carrying out the research.

Our results have shown that in the owner-manager case, research is always conducted jointly for projects targeting independent markets (or market segments), but only for sufficiently high values of the market or high enough synergies between agents for projects targeting a common market (or common market segments). When owners face agency problems instead, the decision of going jointly is taken only for higher values of the market and/or higher synergies. We have shown that owners choose less often to let both their units work together if they face moral hazard than otherwise. It has also been shown that for agents' efforts that range from slight duplicates to slight complements there exist a conflict: privately entrepreneurs either decide to stay alone or to join with only one agent, but socially a joint project with both agents would have been preferred. Entrepreneurs choose too seldomly to make use of possible synergies between agents as compared to what would be socially desirable.

Our results suggest that support should be offered to joint projects, provided that they combine research units and, thereby, exploit synergies.

Results have been obtained taking an exogenously fixed overall value of the market, either independent or common. We have argued that making this assumption was not allowing us to look at any market power effects within our analysis. A clarification on the role of this assumption is now possible. When considering the common markets assumption we have let the projects become rivals. This way, an intermediate case between the no competition at all (the one of the independent markets) and the full competition one, which would correspond to a subsequent stage where firms might have had to compete on the market for selling a produced good had they not chosen to join, has been allowed for. In Fabrizi-Lippert (2004), pure market power considerations are instead considered in model where a project has to be adopted that would lead to an production cost reducing innovation. In that context, firms that originally compete on the market have to decide whether to join and the role of a competition authority is explicitly taken into account to characterize the types of errors that may be made when having to accept or refuse a proposed merger.

In our model the efforts that agents provide have not been bounded ex-ante. This is because the optimal contracts always implement effort levels such that the probabilities of success are well defined. However, the model could be used as well in order to assess the impact of part time versus full time job on the privately offered wage contracts, and on the social welfare. This would be possible by reinterpreting our level of effort as the number of hours worked. Our joint-two agents case would then represent an equivalent to part-time jobs, while the joint-one agent case would play the role of a full time job. This could give an explanation, other than demand side arguments such as fears of job instability or the rigidities introduced by legal constraints into the labor market, on why part-time jobs are rarely observed as compared to full-time jobs. Even when these fears or rigidities were not present, this result might be observed as a consequence of an optimal internal organization decision.

One possible extension of this paper would be to analyze patent litigation issues. This would allow for an additional rationale for the occurrence of joint projects. Firms may desire to join to insure themselves against the risk of facing a litigation, and this effect may contrast with the one we have characterized in our model: the tendency under moral hazard to observe too few joint projects where both agents were kept.

Another interesting extension could be to allow the number of entrepreneurs and agents to vary. Examples of such cases are partnerships such as law firms, where a number of seniors and juniors cooperate within the same organization in a proportion which may be variable. Our model could help understand which would be the optimal organization of such a partnership in terms of the relative number of senior partners versus junior associates.

A Proof of $t_1 = t_2$ for $(J2)$

In this appendix, we show that paying equal transfers in the $(J2)$ case is cost minimizing. To show this, we minimize the transfer implementing a certain probability level, first under the assumptions that efforts are observable and then unobservable.

A.1 Observable efforts

Entrepreneurs employ two agents to whom a contract, that specifies an effort level and transfer(s), is proposed. Each agent then has the choice to accept or reject this contract. Thus, entrepreneurs minimize their transfers paid subject only to their respective (IR) constraints. In this case, the cost of implementing a certain probability level is exactly equal to the disutility of the efforts exerted to achieve this probability level.

The probability of success depending on two agents' efforts, is $p(J2) = \left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$. Owner-managers solve the following minimization problem:

$$\begin{aligned} &\min_{t_1,t_2} C^o(J2) = \min_{t_1,t_2} [t_1 + t_2] \\ &s.t. \quad t_i - \frac{1}{2}e_i^2 \geq 0 \qquad \forall i \qquad\qquad (IR_i) \\ &p(J2) = \left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} \end{aligned}$$

The first order conditions to this minimization problem,

$$\begin{aligned} \frac{\partial C^o(J2)}{\partial e_1} &= e_1 - \lambda \frac{1}{1-\varepsilon}\left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}}(1-\varepsilon)\, e_1^{-\varepsilon} = 0 \\ \frac{\partial C^o(J2)}{\partial e_2} &= e_2 - \lambda \frac{1}{1-\varepsilon}\left(e_1^{1-\varepsilon} + e_2^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}}(1-\varepsilon)\, e_2^{-\varepsilon} = 0, \end{aligned}$$

give us:

$$e_1 = e_2 = e.$$

This implies that symmetric transfers are optimal.

A.2 Unobservable efforts

Replicating the same analysis for the world with moral hazard, requires to consider that now entrepreneurs have to offer contracts specifying the transfer to be paid to their agent(s) depending on each state of nature: a positive bonus in case of success and zero in case of failure, thus, satisfying the (LL) constraints. Since efforts are not observable here, entrepreneurs have to give incentives, take (IC) constraints into account, through transfers, in addition to the (IR) constraints.

The joint entity solves now the following minimization problem:

$$\begin{aligned}
\min_{b_1,b_2} C\left(J2\right) &= \min_{b_1,b_2}\left[p\left(J2\right)\left(b_1+b_2\right)\right] \\
s.t. \quad p(J2) &= \left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} \\
e_i^{-\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}} b_i &= e_i \qquad \forall i && (IC_i) \\
p(J2)b_i-\frac{1}{2}e_i &\geq 0 && (IR_i)
\end{aligned}$$

Given the (LL), the (IR) are never binding. Thus, we can rewrite the program expressed in e_i

$$\begin{aligned}
\min_{e_1,e_2} C\left(J2\right) &= \min_{e_1,e_2}\left[p\left(J2\right)\left(b_1+b_2\right)\right] \\
s.t. \quad p(J2) &= \left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} \\
b_i &= e_i^{1+\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-\varepsilon}{1-\varepsilon}} \qquad \forall i && (IC_i)
\end{aligned}$$

we derive the first order conditions

$$\begin{aligned}
\frac{\partial C^u\left(J2\right)}{\partial e_1} = &\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}} e_1^{-\varepsilon}\left(e_1^{1+\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-\varepsilon}{1-\varepsilon}}+e_2^{1+\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-\varepsilon}{1-\varepsilon}}\right)+ \\
&\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}\left(\left(1+\varepsilon\right)e_1^{\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-\varepsilon}{1-\varepsilon}}-\varepsilon e_1\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-1-\varepsilon}{1-\varepsilon}}\right)+ \\
&\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}\left(-\varepsilon e_2^{1+\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-1-\varepsilon}{1-\varepsilon}} e_1^{-\varepsilon}\right)=0
\end{aligned}$$

$$\begin{aligned}
\frac{\partial C^u\left(J2\right)}{\partial e_1} = &\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{\varepsilon}{1-\varepsilon}} e_2^{-\varepsilon}\left(e_1^{1+\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-\varepsilon}{1-\varepsilon}}+e_2^{1+\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-\varepsilon}{1-\varepsilon}}\right)+ \\
&\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}\left(\left(1+\varepsilon\right)e_2^{\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-\varepsilon}{1-\varepsilon}}-\varepsilon e_2\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-1-\varepsilon}{1-\varepsilon}}\right)+ \\
&\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}\left(-\varepsilon e_1^{1+\varepsilon}\left(e_1^{1-\varepsilon}+e_2^{1-\varepsilon}\right)^{\frac{-1-\varepsilon}{1-\varepsilon}} e_2^{-\varepsilon}\right)=0
\end{aligned}$$

Solving for this problem, leads again to the following result:

$$e_1 = e_2 = e \qquad \Rightarrow \qquad b_1 = b_2 = b.$$

An intuition for this result is that, even though the technology is not convex for $\varepsilon < 0$, the non-linear iso-cost lines give rise to an interior solution for ε not too negative.

B Proposition 1

Proof. (i) For all Δ it is true that

$$\Pi^o\left(S|\, I\right) = \frac{1}{2}\left(\frac{\Delta}{2}\right)^2 < \frac{1}{2}\frac{\Delta^2}{2} = \Pi^o\left(J1\right).$$

(ii) (a) $\Pi^o\left(J2\right) > \Pi^o\left(S|\, C\right)$ if

$$\begin{aligned}
\frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\Delta^2\right) &> \frac{1}{2}\left(\frac{2\Delta}{\Delta+2}\right)^2 \\
2^{\frac{2\varepsilon}{1-\varepsilon}}\Delta^2 &> \frac{4\Delta^2}{\left(\Delta+2\right)^2} \\
2^{\frac{\varepsilon}{1-\varepsilon}} &> \frac{2}{\Delta+2} \\
\Delta &> 2^{-\frac{2\varepsilon-1}{1-\varepsilon}} - 2
\end{aligned}$$

(ii) (b) $\Pi^o\left(J1\right) > \Pi^o\left(S|\, C\right)$ if

$$\begin{aligned}
\frac{1}{2}\frac{\Delta^2}{2} &> \frac{1}{2}\left(\frac{2\Delta}{\Delta+2}\right)^2 \\
\frac{\Delta^2}{2} &> \frac{4\Delta^2}{\left(\Delta+2\right)^2} \\
\frac{1}{2\sqrt{2}} &> \frac{1}{\Delta+2} \\
\Delta &> 2\sqrt{2}-2
\end{aligned}$$

(iii) $\Pi^o\left(J2\right) > \Pi^o\left(J1\right)$ if

$$\begin{aligned}
\frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\Delta^2\right) &> \frac{1}{2}\frac{\Delta^2}{2} \\
2^{\frac{2\varepsilon}{1-\varepsilon}} &> \frac{1}{2} \\
2^{\frac{\varepsilon+1}{1-\varepsilon}} &> 1 \\
\frac{\varepsilon+1}{1-\varepsilon} &> 0 \\
\varepsilon &\in \left]-1, 1\right[
\end{aligned}$$

■

C Proposition 2

Proof. (i) For all Δ it is true that

$$\Pi^u(J1) = \frac{1}{2}\left(\frac{\Delta}{2}\right)^2 > \left(\frac{\Delta}{4}\right)^2 = \Pi^u(S|\,I)$$

(ii) (a) $\Pi^u(J2) > \Pi^u(S|\,C)$ if

$$\begin{aligned}
\frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^2\right) &> \left(\frac{2\Delta}{\Delta+4}\right)^2 \\
2^{\frac{2\varepsilon}{1-\varepsilon}}\frac{\Delta^2}{4} &> 2\frac{4\Delta^2}{(\Delta+4)^2} \\
2^{\frac{2\varepsilon}{1-\varepsilon}} &> 2\frac{16}{(\Delta+4)^2} \\
2^{\frac{\varepsilon}{1-\varepsilon}} &> \sqrt{2}\frac{4}{\Delta+4} \\
\Delta &> 4\sqrt{2}2^{-\frac{\varepsilon}{1-\varepsilon}} - 4
\end{aligned}$$

(ii) (b) $\Pi^u(J1) > \Pi^u(S|\,C)$ if

$$\begin{aligned}
\frac{1}{2}\left(\frac{\Delta}{2}\right)^2 &> \left(\frac{2\Delta}{\Delta+4}\right)^2 \\
\frac{1}{2} &> \sqrt{2}\frac{2}{\Delta+4} \\
\Delta &> 4\sqrt{2} - 4
\end{aligned}$$

(iii) $\Pi^u(J2) > \Pi^u(J1)$ if

$$\begin{aligned}
\frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^2\right) &> \frac{1}{2}\left(\frac{\Delta}{2}\right)^2 \\
2^{\frac{2\varepsilon}{1-\varepsilon}} &> 1 \\
\varepsilon &\in \,]0,1[
\end{aligned}$$

■

D Proposition 3

Proof.

Configurations	$(S\|\,I)$	$(S\|\,C)$	$(J1)$	$(J2)$
$\Pi^u(\cdot)$	$\left(\frac{\Delta}{4}\right)^2$	$\left(\frac{2\Delta}{\Delta+4}\right)^2$	$\frac{1}{2}\left(\frac{\Delta}{2}\right)^2$	$\frac{1}{2}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^2\right)$
$W^u(\cdot)$	$3\left(\frac{\Delta}{4}\right)^2$	$3\left(\frac{2\Delta}{\Delta+4}\right)^2$	$\frac{3}{2}\left(\frac{\Delta}{2}\right)^2$	$\frac{7}{4}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^2\right)$
$p^u(\cdot)$	$\frac{\Delta}{4}$	$\frac{2\Delta}{\Delta+4}$	$\frac{\Delta}{2}$	$2^{\frac{2\varepsilon}{1-\varepsilon}}\frac{\Delta}{2}$

(i) For all Δ it is true that

$$W^u(J1) = \frac{3}{2}\left(\frac{\Delta}{2}\right)^2 > 3\left(\frac{\Delta}{4}\right)^2 = W^u(S|\, I)$$

which is the same problem as in proposition 2 (i).

(ii) (a) $W^u(J2) > W^u(S|\, C)$ if

$$\begin{aligned}
\frac{7}{4}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^2\right) &> 3\left(\frac{2\Delta}{\Delta+4}\right)^2 \\
2^{\frac{2\varepsilon}{1-\varepsilon}}\frac{1}{4} &> \frac{3}{7}\frac{4\cdot 4}{(\Delta+4)^2} \\
2^{\frac{\varepsilon}{1-\varepsilon}}\frac{1}{2} &> \sqrt{\frac{3}{7}}\frac{4}{\Delta+4} \\
\Delta &> 8\sqrt{\frac{3}{7}}2^{-\frac{\varepsilon}{1-\varepsilon}} - 4 \\
\Delta &> 4\left(\sqrt{\frac{3}{7}}2^{\frac{1-2\varepsilon}{1-\varepsilon}} - 1\right)
\end{aligned}$$

(ii) (b) $W^u(J1) > W^u(S|\, C)$ if

$$\begin{aligned}
\frac{3}{2}\left(\frac{\Delta}{2}\right)^2 &> 3\left(\frac{2\Delta}{\Delta+4}\right)^2 \\
\frac{1}{2}\left(\frac{\Delta}{2}\right)^2 &> \left(\frac{2\Delta}{\Delta+4}\right)^2 \\
\frac{1}{2} &> \sqrt{2}\frac{2}{\Delta+4} \\
\Delta &> 4\sqrt{2} - 4
\end{aligned}$$

(iii) $W^u(J2) > W^u(J1)$ if

$$\begin{aligned}
\frac{7}{4}\left(2^{\frac{2\varepsilon}{1-\varepsilon}}\left(\frac{\Delta}{2}\right)^2\right) &> \frac{3}{2}\left(\frac{\Delta}{2}\right)^2 \\
2^{\frac{2\varepsilon}{1-\varepsilon}-1} &> \frac{3}{7} \\
2^{\frac{3\varepsilon-1}{1-\varepsilon}} &> \frac{3}{7} \\
\frac{3\varepsilon-1}{1-\varepsilon}\ln 2 &> \ln 3 - \ln 7
\end{aligned}$$

Assume $1-\varepsilon>0$

$$\begin{aligned}
3\varepsilon\ln 2-\ln 2 &> (\ln 3-\ln 7)(1-\varepsilon)\\
3\varepsilon\ln 2-\ln 2 &> (\ln 3-\ln 7)-(\ln 3-\ln 7)\varepsilon\\
\varepsilon(3\ln 2+(\ln 3-\ln 7)) &> \ln 3-\ln 7+\ln 2\\
\varepsilon &> \frac{\ln 3-\ln 7+\ln 2}{3\ln 2+\ln 3-\ln 7}\approx -0.125\,11
\end{aligned}$$

Assume $1-\varepsilon<0$

$$\begin{aligned}
3\varepsilon\ln 2-\ln 2 &< (\ln 3-\ln 7)(1-\varepsilon)\\
3\varepsilon\ln 2-\ln 2 &< (\ln 3-\ln 7)-(\ln 3-\ln 7)\varepsilon\\
\varepsilon(3\ln 2+(\ln 3-\ln 7)) &< \ln 3-\ln 7+\ln 2\\
\varepsilon &< \frac{\ln 3-\ln 7+\ln 2}{3\ln 2+\ln 3-\ln 7}\approx -0.125\,11
\end{aligned}$$

which is a contradiction to $1-\varepsilon<0$. ■

References

[1] Banal-Estañol, A. and J. Seldeslachts, 2004, "Merger Failures", University of Western Ontario and Universitat Autònoma de Barcelona, mimeo.

[2] Caloghirou, Y., S. Ioannides, and N. Vonortas, 2003, "Research Joint Ventures", *Journal of Economic Surveys*, 17, 541-570.

[3] d'Aspremont, C. and A. Jacquemin, 1988, "Cooperative and Noncooperative R & D in Duopoly with Spillovers", *The American Economic Review*, 78, 5, 1133-1137.

[4] Espinosa, M.P. and I. Macho-Stadler, 2003, "Endogenous formation of partnership with moral hazard", *Games and Economic Behavior,* 44, 172-183.

[5] Fabrizi, S. and S. Lippert, 2004, "How much efficiency gains and price reductions to put as ingredients into an efficiency defense? 'Quanto Basta'", UPV/EHU, DFAEII Working Paper No. 2004-04.

[6] Harrigan, K.R.,1986, *Managing for Joint Venture Success*, Lexington Books.

[7] Holmström, B., 1982, "Moral Hazard in Teams", *The Bell Journal of Economics*, 13, 2, 324-340.

[8] Itoh, H., 1991, "Incentives to Help in Multi-Agent Situations", *Econometrica*, 59, 3, 611-636.

[9] Kamien, M.I., E. Muller and I. Zang, 1992, "Research Joint Ventures and R&D Cartels", *The American Economic Review*, 82, 5, 1293-1306.

[10] Laffont, J.J. and P. Rey, 2000, "Collusion and Group Lending with Moral Hazard", IDEI Université Toulouse 1.

[11] Martinez-Giralt, X. and R. Nicolini, 2004, "On Bilateral Agreements: the Importance of Technological Endowments in Presence of a Learning Process", Universitat Autònoma de Barcelona, Barcelona Economics WP No. 101.

[12] Pammolli, F., 1996, *Innovazione, concorrenza e strategie di sviluppo nell'industria farmaceutica*, Guerini Scientifica, Milan.

[13] Pastor, M. and J. Sandonís, 2002, "Research Joint Ventures vs. Cross Licensing Agreements: an agency approach", *International Journal of Industrial Organization*, 20, 215-249.

[14] Pérez-Castrillo, D. and J. Sandonís, 1996, "Disclosure of Know-how in Research Joint Ventures", *International Journal of Industrial Organization*, 15, 51-75.

[15] Rogerson, W.P., 1985, "The First-Order Approach to Principal-Agent Problems", *Econometrica*, 53, 6, 1357-1368.