INFLUENCE ACTIVITY
AND THE ORGANIZATION OF RESEARCH AND DEVELOPMENT

by

Bruno Cassiman
IESE Business School

E-mail: bcassiman@iese.edu

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** Mailing Address: IESE Business School, Universidad de Navarra, Avenida Pearson 21, 08034 Barcelona, Spain. Tel. 34-936 024 426, Fax. 34-932 534 343.
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Abstract

The organizational design of research and development conditions the incentives of the researchers of the research project. In particular, the organizational form determines the allocation of effort of the researcher between time spent on research and time spent lobbying management. Researchers prefer to spend their time on research. However, the researchers only get utility from performing research if the project is approved for its full duration. Spending time lobbying management for the continuation of the researcher’s project increases the probability that the management observes a favorable signal about the project. Organizing a research joint venture increases the flexibility of the organizational form with respect to the continuation decision. For low correlation between the signals of the partners about the expected profitability of the project, we find that the organization of a research joint venture reduces influence activity by the researchers and increases expected profits of the partners compared to internal research projects. For high correlation between the signals, this result is reversed.

JEL: D23, D82, L22, O32

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1. Introduction

The term “research” covers a wide range of activities from basic or fundamental research, over applied research, to the actual development of a product or process to market strength (Nason (1981)). The type of research project that is considered, is an important element in understanding the choice of how to organize the research project. In particular, we are interested in analyzing the decision of a firm whether to seek out a partner and cooperate on the research project, or to develop the project as an internal R&D project. The objective of the firm is to choose the organizational structure that maximizes the expected profits of the research project. Typically, the research project will involve different stages and must pass several milestones before completion. After each stage, the results and progress of the research project are evaluated and management has to decide whether the project still corresponds to the strategic objectives of the firm. If so, the project is continued and new funds are allocated. The researchers usually care strongly about their research project and its continuation because of the specific investment they sank into the project. This leads the researchers to try to influence the continuation decision by management in favor of continuing the project, regardless of the value of the project to the firm. These influence activities or organizational politics have been documented to be important activities within an organization (see Schilit and Locke (1982), Howell and Higgins (1990), Prasad and Rubenstein (1992), Gresov and Stephens (1993)).

1 The time that researchers spend lobbying management, is time that the researchers do not devote to productive activities. Although organization theorists have noted the importance and studied the effects of influence activities within an organization,
they have refrained from extending their insights to the optimal design of organizations. Given that influence activity affects the expected profitability of the project to the organization, the optimal organizational design needs to take into account its effect on the researchers’ incentives to engage in influence activity (see Milgrom (1988), Milgrom and Roberts (1991), Meyer et al (1992) and Wulf (1997)).

In order to analyze this relation between organizational structure, researchers’ incentives to engage in influence activity, and project characteristics, we develop a stylized model of a research joint venture and an internal research project. The model incorporates what is claimed to be one of the most important benefits of organizing a research joint venture compared to organizing a project internally: the flexibility of the joint venture (Kogut (1991)). Although frequently alluded to in the management literature, the fact that joint ventures increase flexibility and the effect this increased flexibility has on the internal workings of the joint venture is not clear. Our joint venture model is in line with Kogut (1991), where he describes the joint venture as a “real” option to expand. The timing of this expansion, which is associated with the acquisition of the joint venture by one of the partners, is conditional on a signal about the value of the venture. The flexibility of the joint venture is related to the fact that the project can turn out to be profitable for one firm but not for the other. This results in a higher flexibility of the joint venture with respect to the continuation decision compared to an internal R&D project, because the continuation decision in the research joint venture is a function of the signals of all the partners. However, contrary to what is often assumed, we find that this commitment to flexibility in the research joint venture is not necessarily beneficial.
The results of the model are driven by the following observation: the only option for the internal R&D project after a low signal is to liquidate the project, while in the research joint venture, there is the option to renegotiate control over the project. In the internal R&D project, there is no partner to observe a signal about the profitability of the project and as a result, other firms are unable to value this project. This is consistent with the results of Gomeres-Casseres (1987) who finds that subsidiaries of multinational firms are more likely to liquidate compared to joint ventures. In joint ventures, partners are more likely to renegotiate control and ownership structures (Blodgett (1992)). The flexibility of the research joint venture and the allocation of control over the research project are thus interrelated. Renegotiation of control over the research project takes place in the research joint venture whenever the partner in control gets a low signal, while the other partner observes a high signal. Ownership and control are positively correlated but typically do not coincide in a joint venture (Geringer and Herbert (1989)). Ownership conveys to the party not in control the right to veto important operating decisions and the right of first refusal to buy out the other partner.\(^2\) Ownership thus creates an option on the future (Kogut (1983)), or, more appropriately in this model, an option on control over the research project. In an internal R&D project, ownership and control cannot be separated. The research joint venture thus provides an instrument to separate ownership and control, a fact that we associate with the flexibility of the research joint venture. In that respect, this paper is related to Zender (1991) and Aghion and Bolton (1992). These authors view debt as an optimal mechanism for the contingent allocation of control between shareholders and
debtholders. In our model, the research joint venture serves a similar purpose for the contingent allocation of control over a research project between partners.

The main result of the paper states that whether or not the researcher spends more time influencing the continuation decision in the internal R&D project compared to the research joint venture, depends on the correlation between the signals of the potential partners. If the signals of potential partners are highly correlated, the beliefs of the firms are such that the project is only continued if both signals are observed to be high. Hence, the researcher in the research joint venture spends more time influencing the signals because she can only guarantee continuation if both signals are high. If the signals are not highly correlated, the researcher can assure continuation in the research joint venture whenever one of the signals is high. The firm in the internal R&D project cannot condition the continuation policy on the signal of the potential partner. That signal is not observable, given that the other firm did not commit to the partnership. The choice of the organizational design thus implies a commitment to a continuation decision, which can be framed as a choice over ex post information structures. The information set on which to condition the continuation policy in the internal R&D project is coarser than in the research joint venture. If correlation is low, the finer information structure in the research joint venture lowers the influence activities of the researcher compared to the internal R&D project. However, if correlation is high, this result is reversed, where the coarser information structure of the internal R&D project reduces influence activity compared to the finer information structure of the research joint venture. The organizational structure which maximizes expected profits, in many cases corresponds to the one that minimizes
influence activity by the researcher. As a result, the commitment to a more flexible
continuation decision in the research joint venture is not necessarily beneficial to the firm.
Cremer (1995) finds a similar result, where the principal needs to decide on his monitoring
technology. In his model a “better” monitoring technology can hurt the principal, because it
increases the cost of commitment not to renegotiate with the agent.

The results of the model are consistent with the casual observation that research
joint ventures tend to perform more basic research projects compared to internal R&D
departments (Collins and Doorley (1990)). First, the benefits of basic research projects
are less likely to be correlated between the partners in the research project, because these
projects are more likely to come up with unexpected results which could be valuable to at
least one of the partners. Secondly, the results of more basic research projects still need to
be incorporated into new products and processes. As a result, we expect that the eventual
benefits from basic research projects are less likely to be competitive between partners.
The results of the model indicate that if the correlation between the signals of the partners
is low, and if future profits are not likely to be competitive, the organization of a research
joint venture dominates organizing the project internally. Given the characteristics of more
basic research projects, we thus find that these projects are more likely to be organized in
a research joint venture. Organizing a more basic research project internally, creates more
influence activity than when organized in a research joint venture. An alternative
explanation for this observation is the fact that basic research is thought to be less
appropriable than applied research. As a result, firms form research joint ventures in order
to internalize this externality while concentrating internal R&D efforts on the more
appropriable results of applied research and development. Although the appropriability argument seems to explain this observation, it does not account for the organizational design of the research joint venture. In order to solve the externality related to more basic research, firms need to be able to contract on the inputs and share in the costs of the project. These conditions are less likely to be satisfied in the case of basic research. The model in this paper does not rely on the sharing of costs.

The remainder of the paper is organized as follows: in the next section we develop the model. Section 3 derives the equilibrium of the model and analyzes its results. Section 4 concludes with a discussion of possible extensions. Appendix 1 gathers the proofs of the Propositions and some of the more tedious definitions and derivations, and in Appendix 2, we illustrate the results of the model with an example.

2. Model

Consider two firms, firm x and firm y, that each have a single line of business. For the time being we assume that firm x cannot or does not want to replicate firm y’s line of business internally. Firm x is considering one R&D project and can decide to do this R&D project jointly with firm y by forming a research joint venture (RJV) or firm x can do the project internally (IRD). We concentrate on firm x’s decision and assume that the control rights over the project are allocated to firm x at the start of the project, but they can be renegotiated during the game in the research joint venture. The firm which has the control rights over the project pays all the costs of the R&D project. This allows us to focus attention on aspects of organizing a research joint venture other than cost sharing.
and ownership. We will discuss the implications of these assumptions and relax them later on. Each partner in the research project needs to sink an amount $\epsilon$ into setting up the project, where $\epsilon$ is “small”. This can be considered as an initial investment for starting up and committing to the project.

The project employs one researcher or one team of researchers. This researcher engages in preliminary research on the project. However, knowing that the project still needs to pass a final evaluation, the researcher devotes time both to preliminary research and lobbying activities. The lobbying activities are intended to influence management into continuing the research project. The researcher thus allocates her time, $T$, between influence activities, $i$, and research, $t$, on the project. The actual allocation of the researcher’s time is not observed by management, implying that the researcher cannot be rewarded for spending more time on research and less on lobbying management. This assumption seems reasonable, given that finding appropriate measures for evaluating research personnel in reality, is always problematic (Brown and Gobeli (1992)).

The decision of the management whether or not to continue the research project, depends on the expected profitability of the project. The final evaluation of the project is based on a signal, $s$, that the management receives about the expected profitability of the project for that firm. If the project is set up as a RJV between firm x and firm y, we allow for renegotiation of the control (and ownership) of the project between the partners after the signal is observed. The party not in control makes a take-it-or-leave-it offer for control over the research project. In equilibrium the signal is a perfect predictor of the researcher’s allocation of time to research effort. To avoid a simplistic contract where the
researcher is rewarded based on the signal, we assume that the signal is not verifiable by a third party. After the signals have been observed and renegotiation has taken place, the firm that has control over the project needs to decide whether or not to continue the project and sink another amount of capital, F, into the research project for its actual development. Finally, the payoffs are realized. The timing of the game is represented in Figure 1.

<table>
<thead>
<tr>
<th>Organizational Design</th>
<th>Researcher Allocates Time</th>
<th>Firms receive Signal s</th>
<th>Renegotiation of Control</th>
<th>Continuation Decision made</th>
<th>Payoffs realized</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRD or RJV</td>
<td>T = t + i</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Timing of the Game

In order to describe the payoffs, we need to put some more structure on the model. The researcher has limited time to allocate over lobbying management for the continuation of the project and working on the research project. If the researcher spends i time on influence activity, then there is only T−i time left to do research. The researcher realizes private benefits from performing research if the project is continued past the evaluation stage. The rationale for this assumption is that the researcher anticipates that once the funds are committed by the management, the researcher can enjoy performing the actual research after having made a specific investment into the project. If the project is not continued, the researcher will need to find a new project and go through the whole evaluation stage again, i.e. making a new specific investment. We assume that the private benefits that accrue to the researcher from doing research, conditional on the continuation of the project, are increasing in the amount of time devoted to preliminary research, b(T−i). To make the model tractable, we assume that the private benefits of the
researcher are linear in the time devoted to preliminary research: \( b(T-i) = T-i \). The researcher spends all her available time on research or lobbying, given that she is not averse to spending effort. However, lobbying is costly to the researcher because of the opportunity cost of lobbying time. We assume that the researcher is employed by the firm at a fixed wage (which we normalize to zero) and that she is not remunerated on a project by project basis. This could be due to the fact that some tasks that the researcher performs (such as doing “research”) are hard to measure. As a result, it is optimal to pay the researcher a flat wage (see Holmstrom and Milgrom (1991)). Alternatively we could assume that the researcher is infinitely risk averse and can not be motivated by a monetary transfer from the firm (Aghion and Tirole (1997)).

The payoffs of the firms depend on their signal about the expected profitability of the project. Firm i can get one of two signals, \( s_i \), about the expected profitability of the project: a high signal (1) or a low signal (0), \( s_i \in \{0,1\} \). The prior marginal probability without influence activity is \( P(s_i = 1) = \frac{1}{2} \). Organizing a research joint venture implies bringing in another firm. The informational implication of this organization is that both firms get a signal about the profitability of the project to their firm. We define a state of nature, \( k \), when organizing a IRD as \( k \in S_{IRD} = \{s_x \mid s_x \in \{0, 1\}\} = \{0, 1\} \), while when organizing a RJV as \( k \in S_{RJV} = \{(s_x, s_y) \mid s_x, s_y \in \{0, 1\}\} = \{(1, 1), (1, 0), (0, 1), (0, 0)\} \). The signals are usually not perfectly correlated. Note that these signals are not draws from the same distribution on the profitability of the project. Each firm has a specific line of business and the profitability of the project is conditioned by their line of business. The
joint distribution of the signals in the research joint venture is represented in Figure 2, where \( w = \frac{I + \rho}{2} \) and \( \rho \) is the correlation between the signals of the firms.\(^7\)\(^8\)

**Figure 2:** Joint Distribution of Signals in RJV without Influence Activity

The expected profits of firm x for the IRD, conditional on continuing the project depend on the pure research effort of the researcher and the signal the firm received: \( s_x \pi_x(t) \). The signal measures the match of the project with the current or future business prospects of the firm, while \( \pi_x(t) \) measures the potential of this research idea as a function of research effort. The profits of firm x organizing a RJV are \( r(s_x, s_y) s_x \pi_x(t) \), where \( r(1, 1) = \gamma \) and \( r(1, 0) = r(0, 1) = r(0, 0) = 1 \). One of the costs of engaging in cooperative R&D is the possibility that proprietary know-how is leaked to the partner and that through the cooperative venture a new future competitor is created (Contractor and Lorange (1988)). In this case \( \gamma \) is less than one, implying that firm x loses some of its expected future profits through the cooperative venture. On the other hand, partners in a cooperative agreement
can bring in complementary resources and create synergies, which increase the expected future profits for any partner. In this case $\gamma$ is larger than one. However, we will restrict attention to the case where $\gamma \leq 1$, given that it is obvious that the RJV becomes more attractive when the firms (by assumption) create some synergies in the RJV, which cannot be achieved by the IRD. We make the following assumptions on the payoffs:

**Assumption 1.**

1. $\forall 0 \leq t \leq T: \frac{\gamma \pi_x(t)}{2} > F + \epsilon$

2. $\pi_x(t)$ is increasing and continuous in $t$.

Assumption 1.1 guarantees that it is individually rational to consider the project ex ante for any amount of influence activity by the researcher. Implicitly this puts a lower bound on $\gamma$ and eliminates cases where the IRD is ex ante profitable, while the RJV is not. Given Assumption 1.1, we can restrict attention to the effect of influence activity on the continuation policy. Assumption 1.2 indicates that the expected profits of the project are increasing in the time spent by the researcher on preliminary research. The higher the initial research effort, the more potential problems have been resolved and alternative research paths eliminated, and hence, the sounder the project. The profits of firm $y$ are symmetric. In the remainder of the paper we focus on the decision of firm $x$ and drop the firm subscripts when no confusion is possible.

We assume that the profits are not contractible ex ante. Contractibility in this simple setting would imply that the firm can infer the amount of influence activity from the realization of the payoffs and force the optimal amount of influence activity (zero). This assumption could be avoided by constructing a more involved model, without adding any
insights to the results of the paper. We think that it is reasonable to assume that for R&D projects, future profits are not likely to be contractible (Aghion and Tirole (1994)). In addition, we assume that the continuation decision is not contractible. This eliminates contracts where the firms commit to continue a project with some probability, even though they received a bad signal, or commit to pay the research a bonus whenever her project is terminated. The only way in this model to commit to a continuation decision, is by the choice of organizational design.

A first result provides a useful benchmark for the rest of the analysis. This proposition also enlightens the set up of the model, where we want to focus attention on the relation between organizational design and influence activity by the researcher while eliminating other possible effects in the model.

**Proposition 1.** If there is no influence activity by the researcher, \( i = 0 \), and if individual firm profits are the same under both organizational forms, \( \gamma = 1 \), firm x is indifferent between organizing the project as an internal R&D project or as a research joint venture.

Next we need to describe how time spent influencing the continuation decision of management, impacts the problem. The researcher wants to avoid the discontinuation of the project. The project is discontinued for sure if the party in control gets the low signal. Influence activity thus needs to reduce the probability that the low signal is actually observed. Hence, influence activity increases the probability that the management observes the high signal while the true signal is low. In practice, there are many ways that the researcher can try to influence the continuation decision. Researchers spend time dressing up preliminary results from the project, writing memos and giving seminars to convince management of the value of the project. We assume that the probability that the
firm observes a high signal, while the true state is low, is a function of the time that the researcher spends influencing the decision,

\[ P(\hat{s} = 1 | s = 0 ; i) = q(i), \]

where \( \hat{s} \) denotes the signal that management observes and \( s \) denotes the true signal. To simplify the analysis, we assume that \( P(\hat{s} = 1 | s = 1 ; i) = 1 \). If the true signal is high, management will always observe this. Influence activity only tries to avoid a bad evaluation of the project. This assumption does not affect the main insights of the model. The results continue to hold provided that influence activity increases the probability of observing the high signal relative to when no influence is exerted.\(^9\) We make the following assumptions about the influence function:

**Assumption 2.**

1. \( q(i) \) is increasing, concave and twice continuously differentiable in \( i \),
2. \( q(0) = 0, q(T) = 1 \) and \( q'(0) = \infty \),
3. \( \forall 0 \leq i \leq T: \frac{1 - q(i)}{q(i)} \leq (T - i)q'(i) \)

If there is no influence activity by the researcher, then the probability that management observes the high signal while the true signal is low, is zero. By engaging in influence activity, the researcher can increase the probability that management observes the high signal while the true signal is low. As noted above, we assume that if the true signal is high, it will always be revealed as high. Assumption 2.3 is a condition on the likelihood ratio of observing high versus low when the true signal is low. Influence activity needs to be sufficiently successful in changing the observed signal from the true signal.
when the true signal is low. In Appendix 2, where we illustrate the model with an example, we identify a class of functions that satisfy this assumption.

In the research joint venture we assume that influence activity independently affects the signals of firm x and firm y for a given amount of influence activity.\textsuperscript{10,11} Success by the researcher in turning the low signal of one firm into a high signal is independent of success with respect to the other signal. At the same time, communication about the project can be sent simultaneously to both partners, while seminars are attended by decision makers of both firms. It is then straightforward to extend the effect of influence activity to the case of the research joint venture where the researcher concentrates on avoiding a low signal. The joint distribution of the observed signals, with a level of influence i and correlation w, is represented in Figure 3.\textsuperscript{12} The marginal distribution of the observed signal for one of the partners is, \( P(\hat{x} = 0 ; i) = \frac{1}{2} - \frac{q(i)}{2} \) and \( P(\hat{x} = 1 ; i) = \frac{1}{2} + \frac{q(i)}{2} \). This coincides with the distribution of the observed signal in the IRD.

**Figure 3: Joint Distribution of Signals in RJV with Influence Activity**

\[
\begin{array}{c|c|c}
\hat{x} = 0 & \hat{x} = 1 \\
\hline
\text{Firm x} & \text{Firm y} & \\
\hline
\hat{x} = 0 & \frac{w - q(i)^2}{2} - 2q(i)\left(1 - q(i)\frac{w}{2}\right) & \frac{1 - w}{2} + q(i)(1 - q(i))\frac{w}{2} - q(i)\frac{1 - w}{2} \\
\hat{x} = 1 & \frac{w - q(i)^2}{2} - 2q(i)\left(1 - q(i)\frac{w}{2}\right) & \frac{1 - w}{2} + q(i)(1 - q(i))\frac{w}{2} - q(i)\frac{1 - w}{2} \\
\end{array}
\]
\[ \hat{s}_i = 1 \]
\[ \frac{I - w}{2} + q(i)(1 - q(i)) - q(i) = \frac{I - w}{2} + q(i) - q(i) \]
\[ \frac{w}{2} + q(i)^2 w + 2q(i) \]

To describe the equilibrium, we need to introduce some more notation, after which Proposition 2 states a second intuitive result and points to the sources of inefficiency of influence activity. Given that the signal reveals something about the business opportunities of the project, we assume that the researcher has no private information about the true signal. The only private information in the model is a hidden action by the researcher, namely the allocation of the researcher’s time between influence and research activity (see also Milgrom (1988)). Through her influence activities, the researcher thus tries to jam the signal(s) of the decision maker(s) (Fudenberg and Tirole (1986)).

**Definition 1a.** Define \( \mu(k \mid \hat{s}; i) \) as the beliefs of the firm that the true state of nature is k after observing \( \hat{s} \) when the researcher spends i time on influence activity where \( k, \hat{s} \in S^{IRD} \) when organizing the project internally or \( k, \hat{s} \in S^{RJV} \) when organizing a research joint venture.

**Definition 1b.** Define \( \lambda(\hat{s}; i) \) as the probability that state \( \hat{s} \) is observed when the influence level is i, where \( \hat{s} \in S^{IRD} \) when organizing the project internally or \( \hat{s} \in S^{RJV} \) when organizing a research joint venture.

**Definition 2.** A **Continuation Policy** is a function, \( d_j^i : S \rightarrow \{0, 1\} \), where \( d_j^i(s) = 1 \), implies that the project is continued after signal s is observed and where \( d_j^i(s) = 0 \), implies that the project is discontinued after signal s is observed and \( j \in \{IRD, RJV\} \).

**Definition 3a.** Define \( \Pi_f^j(t, i, \hat{s}) \) as the expected profits of firm \( f \in \{x, y\} \) conditional on continuation of the project, when signal \( \hat{s} \) is observed, given research effort t, influence level i, and, when the organizational design is \( j \in \{IRD, RJV\} \).
**Definition 3b.** Define $V_f(d^j, i)$, as the expected profits of firm $f \in \{x, y\}$, with continuation policy $d^j$ and influence level $i$, when the organizational design is $j \in \{IRD, RJV\}$.

**Proposition 2.** Any positive amount of influence activity, $i > 0$, reduces the firm’s expected profits.

Proof: If there is no influence activity ($i=0$), the expected profits of firm $x$ are: $\lambda(\hat{s}_x = 1; 0) [\pi(T) - F]$. If $\gamma = 1$, the firm is indifferent whether an IRD or a RJV is organized (Proposition 1).

1. Compare to IRD with influence activity.
   The expected profits in the IRD are: $\lambda(\hat{s}_x = 1; i) [\mu(s_x = 1 | \hat{s}_x = 1; i) \pi(t) - F]$, where $i > 0$.
   From Bayes rule we know that: $\mu(s_x = 1 | \hat{s}_x = 1; i) = \frac{\lambda(\hat{s}_x = 1; i)}{\lambda(\hat{s}_x = 1)}$

The difference between the profits of the IRD with and without influence activity is:

$$\Delta = \lambda(\hat{s}_x = 1; 0)[\pi(T) - \pi(t)] + \lambda(\hat{s}_x = 1; i) - \lambda(\hat{s}_x = 1; 0)F$$

Given that $i > 0$, $T > t$ and $\lambda(\hat{s}_x = 1; i) \geq \lambda(\hat{s}_x = 1; 0)$. Profits are strictly increasing in $t$. This implies that this difference is strictly positive.

The inefficiency of influence activity in the IRD derives from two sources. First, spending time lobbying, is time not spent doing research which would increase the expected profitability of the project. Secondly, influence activity leads to continuing the project, when in fact the project is valueless to the firm. The firm loses its investment, $F$, in that case.

2. Compare to RJV with influence activity.
   We need to discuss two cases, depending on the continuation policy in the RJV. We will show that these are the only relevant cases.

**Case a:** $d^{RJV}(\hat{s}_x = 1, \hat{s}_y = 1) = d^{RJV}(\hat{s}_x = 0, \hat{s}_y = 1) = d^{RJV}(\hat{s}_x = 1, \hat{s}_y = 0) = 1; d^{RJV}(\hat{s}_x = 0, \hat{s}_y = 0) = 0$.

After some manipulation (using Bayes rule), we find that the difference in profits because of influence activity is:

$$\Delta \geq \lambda(\hat{s}_x = 1, \hat{s}_y = 1; 0) [\pi(T) - \pi(t)] + \lambda(\hat{s}_x = 1, \hat{s}_y = 0; 0) [\pi(T) - \pi(t)]$$

$$+ \lambda(\hat{s}_x = 1, \hat{s}_y = 1; i) + \lambda(\hat{s}_x = 1, \hat{s}_y = 0; i) - \lambda(\hat{s}_x = 1, \hat{s}_y = 1; 0) - \lambda(\hat{s}_x = 1, \hat{s}_y = 0; 0)F$$

Note that the last term is non-negative. This term indicates the cost of influence activity, because it specifies the expected cost of continuing the project, while in
reality the firm has no profit to gain from the continuation. The first two terms are losses due to time spent influencing the decision, instead of doing research. This is very similar to the case of the IRD.

**Case b:**  
\[ d^{RJV}(\hat{s}_x = 1, \hat{s}_y = 1) = 1; \]  
\[ d^{RJV}(\hat{s}_x = 0, \hat{s}_y = 1) = d^{RJV}(\hat{s}_x = 1, \hat{s}_y = 0) = d^{RJV}(\hat{s}_x = 0, \hat{s}_y = 0) = 0. \]

The difference in profits due to influence activity is:

\[
\Delta = \lambda(\hat{s}_x = 1, \hat{s}_y = 1; 0)\pi(T) - \pi(t)\]  
\[ + \lambda(\hat{s}_x = 1, \hat{s}_y = 0; 0)\pi(T) - \pi(t)\]  
\[ + \lambda(\hat{s}_x = 1, \hat{s}_y = 0; i)\pi(T) - \lambda(\hat{s}_x = 1, \hat{s}_y = 0; 0)\pi(t)\]  
\[ + \mu(\hat{s}_x = 1, \hat{s}_y = 0; \hat{s}_x = 1, \hat{s}_y = 0; 0)\pi(t)\]

Note that this difference is non-negative. In this case there are three sources of inefficiencies of influence activity. First, there is less time to do research. Second, there is a cost of continuing the project while it is not worthwhile for the firm to do so, given the true signal. These inefficiencies are similar to the previous cases. The third term shows the loss due to a non-optimal discontinuation rule. It would be profitable to the firm to continue the project when \((\hat{s}_x = 1, \hat{s}_y = 0)\) is observed and the true signal is \((s_x = 1, s_y = 0)\). For all cases we have shown that influence activity is costly to the firms.

Proposition 2 distinguishes between two sources of inefficiency due to influence activity. A first inefficiency arises because time spent on influence activity reduces the actual research effort. A second source of inefficiency is the result of inefficient continuation decisions that are made due to influence activity. Some good projects are prematurely terminated while other bad projects are continued up to their full term. As a result, influence activity is expected to worsen the success rate of projects conditional on being initiated. One corollary of Proposition 2 is that, everything else equal, the firms prefer less influence activity to more within the same organizational form. We are now ready to analyze the equilibrium of this model of imperfect information.

### 3. Equilibrium

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The equilibrium concept used is *Perfect Bayesian Equilibrium*. In the first two subsections we solve for the equilibrium in the subgames where the firm organizes an IRD project or a RJV. We compare the equilibrium outcomes for these subgames in subsection 3.

### 3.1 The Internal R&D Project

A *Perfect Bayesian Equilibrium* of the IRD subgame is a triplet \((i^*, d^*(·), \mu^*(·))\) where the following three conditions are satisfied:

1. \(i^* \) maximizes the expected benefits of the researcher: 
   \[
   \max_{i} \left( T - i \right) \sum_{s \in S^{IRD}} d'(\hat{s}) \lambda(\hat{s}; i)
   \]

2. \(d^*\) satisfies \(V_x^{IRD}(d^*, i^*) \geq V_x^{IRD}(d, i^*), \forall d: d \text{ is a Continuation Policy for the IRD.}\)

3. \(\mu^*(k | \hat{s} ; i^*)\) satisfies \(\mu(k | \hat{s} ; i^*) \geq 0 \forall k, \hat{s} \in S^{IRD}\) and \(\sum_{k \in S^{IRD}} \mu(k | \hat{s} ; i^*) = 1, \forall \hat{s} \in S^{IRD}\). These beliefs of the firm are derived from Bayes Rule where possible.

If the firm observes the high signal, the firm continues the project whenever \(\Pi_x^{IRD}(t, i, \hat{s}_i = 1) \geq 0\). Assumption 1 assures that this condition holds and guarantees a dominant strategy for the firm in the internal R&D project. Obviously, if the signal is low, the firm knows the project is junk and will discontinue it. The optimal continuation strategy of the firm in an IRD then is: \(d^*(\hat{s}_i = 1) = 1, d^*(\hat{s}_i = 0) = 0\). The optimal influence effort by the researcher, taking into account the dominant strategy of the firm, maximizes: \(\int d \mu^*(\cdot)\)
3.2 The Research Joint Venture

A Perfect Bayesian Equilibrium of the RJV subgame is a triplet \((i^*, d^*(\cdot), \mu^*(\cdot))\) where

1. \(i^*\) maximizes the expected benefits of the researcher: 
\[
(T - i) \lambda(\hat{s}, 1; i) = (T - i) \frac{1 + q(i)}{2}
\]

2. \(d^*\) satisfies 
\[
V_{x}^{\text{RJV}}(d^*, i^*) + V_{y}^{\text{RJV}}(d^*, i^*) \geq V_{x}^{\text{RJV}}(d, i^*) + V_{y}^{\text{RJV}}(d, i^*), \quad \forall \ d: d \text{ is a Continuation Policy for the RJV.}
\]

3. \(\mu^*(k \mid \hat{s}; i^*)\) satisfies \(\mu(k \mid \hat{s}; i^*) \geq 0\) \(\forall \ k, \hat{s} \in S^{\text{RJV}}\) and \(\sum_{\hat{s} \in S^{\text{RJV}}} \mu(k \mid \hat{s}; i^*) = 1 \forall \hat{s} \in S^{\text{RJV}}\).

These beliefs of the firms are derived from Bayes Rule where possible.

Before the continuation policy is implemented, we allow for renegotiation of ownership and control. As such, the continuation policy maximizes the joint profits of the RJV. If there is a positive level of influence activity, all information sets are reached in equilibrium and beliefs are formed according to Bayes rule (see Appendix 1). Given the firms’ beliefs about the true state of nature after observing the signal about the expected profitability of the project, we can derive the optimal continuation policy of the research joint venture. It is easy to check that the optimal continuation policy requires \(d^*(\hat{s}_x = 1, \hat{s}_y = 1) = 1\) and \(d^*(\hat{s}_x = 0, \hat{s}_y = 0) = 0\). If \((\hat{s}_x = 1, \hat{s}_y = 0)\) is observed, firm \(x\) decides on continuing the project if the following condition holds:

\[
d^*(\hat{s}_x = 1, \hat{s}_y = 0) = 1 \iff \Pi_x^{\text{RJV}}(t, i, \hat{s}_x = 1, \hat{s}_y = 0) \geq 0.
\]
Condition (1) holds whenever the firm attributes enough probability to the event that in the true state one firm has a high signal. This condition turns out to be pivotal in the remainder of the analysis. If \((\hat{s}_x = 0, \hat{s}_y = 1)\) is observed, firm \(x\) would scrap the project. However, firm \(y\) will veto this decision and obtain the control rights in the RJV through renegotiation and pay the continuation costs whenever the symmetric condition to Condition (1) holds for firm \(y\).\(^{16}\) If Condition (1) holds, the optimal continuation policy is:

\[
\begin{align*}
    d^*(\hat{s}_x = 1, \hat{s}_y = 1) &= d^*(\hat{s}_x = 0, \hat{s}_y = 1) = d^*(\hat{s}_x = 1, \hat{s}_y = 0) = 1, \\
    d^*(\hat{s}_x = 0, \hat{s}_y = 0) &= 0.
\end{align*}
\]  

(2)

The researcher’s problem then becomes to maximize:\(^{17}\)

\[
\left( T - t \right) \left[ I - (1 - q(i))^2 \right] w
\]

Lemma 1. For any level of continuation costs, \(F\), there exists a critical correlation level for which Condition (1) is violated for higher levels of correlation: \(\forall \, F > 0: \exists \, w^*; 0 < w^* < 1\) and Condition (1) is violated \(\forall \, w > w^*\).

Lemma 1 implies that the continuation policy defined in (2) cannot be an equilibrium for all \(w\). For high levels of correlation between the firms’ signals, continuation after observing one high and one low signal is not optimal. For a high level of correlation, the firm attributes a high conditional probability on both firms having a low signal. As a consequence of influence activity, the firms change their continuation policy. Therefore influence activity introduces an inefficiency in the continuation decision. We derive the following comparative static result on the critical correlation level:

Proposition 3. The critical correlation level is decreasing in the continuation costs, \(F\), of the research project: \(\frac{d \, w^*}{dF} < 0\)
As the costs of continuing the project, \( F \), increase, Condition (1) will be violated for lower levels of correlation between the signals of the partners. As a result of influence activity, the level of the continuation costs matter. Whenever \( w > w^* \), the RJV only continues the R&D project when both signals are observed to be high and the optimal continuation policy becomes:

\[
\begin{align*}
\text{d}^*(\hat{s}_x = 1, \hat{s}_y = 1) &= 1, \text{ and,} \\
\text{d}^*(\hat{s}_x = 0, \hat{s}_y = 1) &= \text{d}^*(\hat{s}_x = 1, \hat{s}_y = 0) = \text{d}^*(\hat{s}_x = 0, \hat{s}_y = 0) = 0. \quad (3)
\end{align*}
\]

In that case the researcher's equilibrium influence effort is determined by maximizing:

\[
(T - i) \left[ q(i) + (1 - q(i))^3 \frac{w}{2} \right]
\]

As noted in Proposition 2, influence activity can cause several inefficiencies. First, influence activity is costly to the firm because it reduces the research effort by the researcher. Secondly, it worsens decision making. On the one hand, some projects are continued when it is unprofitable to do so. On the other hand, another inefficiency in the continuation decision is created when the correlation of the signals is high. In that case, the firms observing one high and one low signal will be very suspicious about the observation and prefer to discontinue the project, believing that in the true state both signals are low. Influence activity thus forces the firm to change the efficient continuation decision, i.e. continuing the project whenever one of the firms receives a high signal, to the continuation policy defined in (3). This is exactly when Condition (1) is violated. The following comparative statics can be derived on the influence activity of the researcher in the RJV:
Proposition 4. For low levels of correlation, influence activity in the RJV is increasing in the correlation of signals. For high levels of correlation, this result is reversed:

\[ \frac{\partial i^{RJV}}{\partial w} > 0 \text{ if } w < w^*; \quad \frac{\partial i^{RJV}}{\partial w} < 0 \text{ if } w > w^* \]

The intuition for this result is as follows: If \( w < w^* \), the researcher should only be concerned if the true signal is low for both firms. The likelihood of this being the case increases with the correlation and as a result, influence activity increases with correlation.\(^{19}\) If \( w > w^* \), the researcher can only obtain continuation if both firms observe high signals. As correlation increases, the likelihood of the true signal being high for both firms increases. Increased correlation thus reduces the need for influence activity by the researcher.\(^{20}\)

3.3 Relating the IRD and the RJV

In this subsection we attempt to compare the outcome when the firm organizes the project as an IRD with the case where the firm decides to perform the project with a partner in a RJV. We state our main finding in Proposition 5:

Proposition 5. For low levels of correlation between the partners’ signals, the researcher spends more time in influence activities in the IRD compared to the in the RJV. This result is reversed for high levels of correlation: If Assumption 2 holds, then \( \forall w \leq w^*: i^{IRD} > i^{RJV} \), and, \( \forall w > w^*: i^{IRD} < i^{RJV} \).

The proposition states that whether or not the researcher spends more time influencing the continuation decision in the IRD compared to the RJV, depends on the correlation between the signals of the potential partners. If the signals of potential partners are highly correlated, the researcher in the RJV spends more time influencing the continuation decision of the RJV. Since Condition (1) is violated in this case, the
researcher can only guarantee continuation if both signals are high. This requires more lobbying effort. If the signals are not highly correlated, the researcher can assure continuation in the RJV whenever one of the signals is high. In the IRD, the project is continued whenever the firm observes the high signal. The firm in the IRD cannot condition the continuation policy on the signal of the potential partner. That signal is not observable, given that the other firm did not commit to the partnership by investing the initial set up cost $\epsilon$. The choice of the organizational design thus implies a choice over information structures (see footnote 7). The information set in the IRD is coarser than in the RJV. If correlation is low, the finer information structure in the RJV lowers the influence activities of the researcher compared to the IRD. If correlation is high, this result is reversed, where the coarser information structure of the IRD reduces influence activity compared to the finer information structure of the RJV. The choice of organizational design thus serves as a commitment to a continuation decision. In the absence of influence activities, the firm is indifferent about the choice of organization. It is interesting to note is that these results are independent of the actual level of the profits in the RJV versus the IRD. This follows from the fact that Condition (1) is determined by the expected profits of firm x when observing a high signal while firm y observes a low signal. The project is worthless to firm y in this case and as a result firm x does not expect firm y to continue developing competitive products with the final results from the research project.

In order to analyze the choice of the organizational design by firm x, we need to compare expected profit levels under both organizational designs. Define $\gamma^*(w, F)$ such
that the expected profits of firm \(x\) in the IRD are equal to the expected profits of firm \(x\) in the RJV, while anticipating the optimal levels of influence activity by the researcher in both organizations. At \(\gamma^*\), the firm is ex ante indifferent between organizing the project as an IRD or as a RJV, where \(\gamma^*\) indicates the percentage reduction in profits that the firm is willing to sustain in the RJV as to be indifferent between the IRD and the RJV. Obviously, if there is no influence activity, \(\gamma^* = 1\). This is just a restatement of Proposition 1.

**Proposition 6.** For low levels of correlation, the RJV trades off future expected profits for lower levels of influence activity: Suppose \(0 < w < w^*\), then \(\gamma^*(w, F) < 1\).

The intuition for this result is straightforward. For low levels of correlation, the researcher spends more time on influence activities in an internal R&D project than in the RJV. Given equal levels of influence activities, firm \(x\) is indifferent between the IRD and the RJV. Therefore the RJV, while having the same continuation policy as the IRD, can trade off some future expected profits in case both firms get the high signal, in return for lower levels of influence activities. It is also easy to show that \(\gamma^*(w, F)\) is increasing in \(w\), when \(w < w^*\). Meaning that the acceptable level of ex post competition between partners is decreasing in the correlation of the signals.

When correlation is high, it is not clear whether the IRD or the RJV dominates. In Appendix 2 we give an example of both cases. To understand the intuition for the case where \(w > w^*\), we examine the difference in expected profits between the IRD and the RJV. After some manipulation, using the counter factual that we can observe the signal of
the potential partner in the IRD, we get that the expected profits in the IRD are larger than the profits in the RJV iff

\[
\Delta = \lambda(\hat{s}_i = 1, \hat{s}_j = 1 ; i)\mu(s_i = 1, s_j = 1 | \hat{s}_i = 1, \hat{s}_j = 1 ; i)\pi(t^{q}) - \gamma \pi(t^{w})
\]

\[
+ \lambda(\hat{s}_i = 1, \hat{s}_j = 1 ; i)\mu(s_i = 1, s_j = 0 | \hat{s}_i = 1, \hat{s}_j = 1 ; i)\pi(t^{q}) - \pi(t^{w})
\]

\[
+ \lambda(\hat{s}_i = 1, \hat{s}_j = 0 ; i)\mu(s_i = 1, s_j = 0 | \hat{s}_i = 1, \hat{s}_j = 0 ; i)\pi(t^{q}) - F \geq 0
\]

Given that there is more influence activity in the RJV than in the IRD and given that there are no synergies between the firms (\(\gamma \leq 1\)), the first two elements of this difference are positive.\(^{21}\) The last part of the expression is negative by the fact that \(w > w^*\) and becomes more negative as \(w\) increases. As a result, the overall sign of this expression is ambiguous. The trade off between the IRD and the RJV for high levels of correlation is as follows: in the IRD the firm experiences a lower lobbying effort by the researcher and at the same time there is no competitive effect as in the RJV. However, in the IRD the firm, when observing a high signal, can not discriminate between the case where the potential partner would observe a high signal or a low signal due to its coarser information structure. If the firm would have the ability to observe that the signal of the other firm is low, it would discontinue the project, given that continuing the project has a negative expected value. This follows from the fact that Condition (1) is violated. The RJV allows the firm to screen for this case and thus avoid this negative expected profit outcome. There thus exists a trade off between the IRD and the RJV where influence activity (and competition) is traded off for a coarser information structure. The net effect depends on the exact specification of the model. The result that a finer information structure for evaluating the project could hurt the firm, is interesting in its own respect. Cremer (1995) finds a similar result, where the principal needs to decide on his monitoring
technology. In his model a better monitoring technology can hurt the principal, because it increases the cost of commitment not to renegotiate with the agent.

Although our model is stylized, its predictions are consistent with some of the casual observations related to the nature of research and development and its organization. The model is consistent with the stylized fact that RJVs tend to be employed for projects that are more “basic” than applied. The reason is as follows. It seems plausible that more applied projects involve more correlated information among the partners. This is because “basic research is more likely to lead to “unexpected” results” (Nason (1981)). Hence, results could be valuable to at least one of the partners. A second related fact is that “the output of basic research is never some final product to which the market place can attach a price tag” (Rosenberg (1990)). Therefore, the expected profits of a research project between firms are less correlated and less competitive for more basic research projects. When the correlation between the signals is low and future profits are not too competitive, the model predicts that research projects will be organized in a RJV. This is consistent with the observation that RJVs perform research projects that are of a more basic nature compared to internal R&D projects.

4. Extensions
4.1 Divisionalization and Diversification

An important assumption about the firms in the model is that they operate in a single business. As a result they are unable to create the organizational flexibility of the RJV internally and thus an internal R&D project can not mimic the research joint venture. This begs the question whether diversified firms could create the same environment as in the
joint venture. Indeed, suppose the firm has two divisions in different lines of business. An internal R&D project as a joint venture across divisions could create the same incentives for researchers as a joint venture would. The signals that the different divisions observed, would not be perfectly correlated and create a similar flexibility in the continuation decisions of research projects as in the research joint venture. Unrelated diversification, which is measured with respect to the product markets of the divisions and not their technological distance, would reduce the correlation within the signal structure of the firm even more than related diversification. In that respect, the observation that central R&D labs of diversified firms perform more basic research projects through which these firms try to extend their core competence is consistent with the model. Diversified firms would thus realize economies of scope as a result of less influence activity and more research effort by the researchers without the divisions necessarily sharing the costs of a research project.\textsuperscript{23} An empirical prediction resulting from this argument is that we should observe more research joint ventures between non-diversified firms than between diversified firms, because diversified firms can create a similar flexibility by engaging in internal R&D projects across divisions. The central R&D lab of a firm that is divisionalized according to geographic markets, however, will not outperform R&D projects organized within each division, because we expect the signals of the divisions in this firm to be highly correlated. There is some empirical evidence of a close relation between diversification and research joint ventures. Scott (1988) suggests that there is actually some substitution between R&D in diversified firms and research joint ventures. He claims that the introduction of the National Cooperative Research Act (NCRA) in 1984, which made the formation of
research joint ventures less costly for firms, might have resulted in a substitution of diversified R&D for cooperative ventures. In a large sample database of firms that do and do not organize research joint ventures, Vonortas (1997) distinguishes two types of firms: the internally diversified firms and firms that engage in research joint ventures as a diversification strategy which creates technological “options”. He nevertheless finds that there remain important similarities between these two groups such as the average R&D intensity of the destination industry and the observed complementarity between industries that these firms combine either internally or through a research joint venture.

4.2 Size of the RJV and Research Institutes

Another possibly interesting extension of the model is to increase the number of firms that participate in the RJV. Technically, it is not immediately obvious how to extend the signal structure to more than two firms. The intuition, however, would be similar. Increasing the number of participants increases the likelihood that at least one firm gets a high signal and is willing to continue the project. In the limit, when correlation between signals is not perfect, the project is continued for sure and there is no influence activity by the researcher. All her effort goes into research, which increases the expected future profits of the research project. However, we would expect that increasing the number of firms, increases the likelihood that future profits are competitive. In the notation of the model, this means that $\gamma(n)$ is decreasing in the number of firms. It is reasonable to conjecture that the marginal benefits of increasing the number of member firms through reduced influence activity decreases fast, while its marginal cost, the reduction in benefits through expected future competition, increases fast. This would lead to an optimal number of
partners in the research joint venture. A plausible extension of Proposition 6, would be that the optimal number of member firms in the RJV is decreasing in the correlation between signals (however defined). We expect only one member firm (IRD) for a high level of correlation, while we expect many member firms for low levels of correlation. The parallel between more basic research projects versus more applied projects is readily extended: we expect more member firms to join a more basic research project. For example, the Microelectronics and Computer technology Corporation (MCC), which is considered to engage in more basic research, has 22 member firms. However, more applied research projects in microelectronics and computer technology, typically have only a few member firms (Cassiman (1998)). An alternative mechanism that would eliminate influence activity by the researchers, is to organize a research institute. The research institute would commit to continue any project that has been commissioned. At some point it might be more efficient to organize a research institute while limiting the competitive effect of research joint ventures by restricting the number of members. Without this commitment to continue all the projects, the institute with private funding of its research would operate exactly as the research joint venture modeled in the paper. Hence, the model could shed some light on the recent surge in privately but jointly funded basic research at universities.

4.3 Qualitative versus Quantitative Evaluation Measures and Project Specific Investments

A third observation is that performance in research is usually measured through a combination of quantitative and qualitative measures. The more basic the research project, the more weight on qualitative measures in the evaluation process (Brown and Gobeli (1992)). We suggest that qualitative measures of performance are more easily influenced
by the researcher than quantitative measures. Related, Pfeffer et al. (1976) have found that environments that are subject to conditions of high uncertainty—such as is the case with basic research—are typically governed by more particularistic (“subjective”) decision criteria. They show that these environments are more subject to influence activity. Therefore, we would expect that when qualitative performance measures are important in the evaluation process, the marginal benefit of influence activity is higher. As a result, we expect more influence activity in those cases. This would tend to favor RJVs that limit influence activity compared to IRDs in more basic research projects. In terms of the model, the probability that the firm observes a high signal, while the true signal is low, would be a function of the level of influence activity and the relative importance of qualitative to quantitative performance measures in evaluating the merits of the research project. Intuition suggests that moving to more qualitative evaluation measures, which we consider as a sign of more basic research projects, favors the organization of RJVs more than IRDs. If in addition the non-verifiable private benefit of the researcher, which is related to her specific investment into the project, increases, continuation of the project becomes more important to the researcher. We expect that time spent on influence activity would increase as a result. In a survey of scientists and engineers, Ritti (1968) found that among engineers, 69% say it is very important to have the opportunity to help their company increase profits. Among research scientists, only 28% find this very important. In contrast, 88% of the scientists view publication in technical journals as very important. Premature discontinuation of a research project restricts the prospect of high quality publications about the results of the research. This matters more to scientists than
to engineers, because scientists typically work on more basic research projects. This enhances the expected profitability of a more basic research project organized as a RJV compared to an IRD.

4.4 Cost Sharing

In the model we purposefully abstracted away from any cost sharing in the RJV. Note that the assumption that profits in the low state are zero only allows for actual cost sharing when both firms observe the high signal. In all other cases, the firm with the low signal will refuse to continue the project. As such, the main result of the paper remains valid under cost sharing. In particular, the critical correlation level remains unchanged, given that one firm will have to bear all the costs after observing the high signal while the partner observes a low signal. This result can be generalized, given that the researcher only cares about the continuation of the project and not which firm is in control. As long as $s_x \pi(t) + s_y \pi(t) > F$, renegotiation between the partners will insure continuation of the project when correlation is low and there will exist a critical $w^*$ such that expected profits are zero when one firm observes a high signal and the other a low signal. Cost sharing will improve the expected profitability of the RJV compared to the IRD. This does not affect the results of Proposition 6, that the RJV is preferred to the IRD when $w < w^*$. If $w > w^*$, the effects of cost sharing counterbalance the negative effect of competitive future profits in the RJV. Another effect of cost sharing is that Proposition 1 does not hold when firms share costs after both observing a high signal. Allowing cost sharing thus breaks the indifference of firms between a RJV and an IRD when there is no influence activity by the researcher. Extending the model to endogenously account for cost sharing, might
generate some interesting insights into the evolution of ownership structures of research joint ventures. Suppose that the firms start by setting up a 50-50 RJV. This might be the outcome of a bilateral bargaining game. After the signals are revealed, the ownership shares are renegotiated whenever the firms do not observe the same signal. The share in the continuation costs of the partner with the high signal is increased, while that of the partner with the low signal is decreased so as to assure his participation in the project. A consistent empirical prediction is that the lower the correlation between the signals, which we associated with more basic research projects, the more likely there will be shake ups in the ownership structure of the RJVs. A careful analysis of this extension, however, is left for future research.
Appendix 1: Proofs of Propositions

Proof of Proposition 1
Given the low signal, firm x gets zero profits. In that case firm x does not care whether the project is discontinued or if control is given to firm y, since the firm in control pays full continuation costs and the organization, by assumption, does not influence the researcher’s effort allocation.

Conditional Probabilities in RJV
If both true signals are low, the signal observed by management has the following properties:
\[
P(\hat{s}_x = 1, \hat{s}_y = 1 \mid s_x = 0, s_y = 0 ; i, w) = q(i)^3
\]
\[
P(\hat{s}_x = 1, \hat{s}_y = 0 \mid s_x = 0, s_y = 0 ; i, w) = P(\hat{s}_x = 0, \hat{s}_y = 1 \mid s_x = 0, s_y = 0 ; i, w) = q(i)(1 - q(i))
\]
\[
P(\hat{s}_x = 0, \hat{s}_y = 0 \mid s_x = 0, s_y = 0 ; i, w) = (1 - q(i))^3
\]
If one of the true signals is high while the other is low, the signal observed has the following properties:
\[
P(\hat{s}_x = 1, \hat{s}_y = 1 \mid s_x = 1, s_y = 0 ; i, w) = P(\hat{s}_x = 1, \hat{s}_y = 1 \mid s_x = 1, s_y = 1 ; i, w) = q(i)
\]
\[
P(\hat{s}_x = 0, \hat{s}_y = 0 \mid s_x = 0, s_y = 1 ; i, w) = P(\hat{s}_x = 1, \hat{s}_y = 0 \mid s_x = 1, s_y = 0 ; i, w) = 1 - q(i)
\]
If both true signals are high, this is always observed by management:
\[
P(\hat{s}_x = 1, \hat{s}_y = 1 \mid s_x = 1, s_y = 1 ; i, w) = 1
\]

Definitions of Expected Profits
Given definitions 1 through 4, we can derive the following expressions for the expected profits of firm x (the expected profits of firm y are similarly defined):
\[
\Pi_{x \text{IRD}}(t, i, \hat{s}) = \mu(s_x = 1 \mid \hat{s}; i) \pi(t) - F.
\]
\[
\Pi_{x \text{RJV}}(t, i, \hat{s}) = \mu(s_x = 1, s_y = 1 \mid \hat{s}; i) \gamma \pi(t) + \mu(s_x = 1, s_y = 0 \mid \hat{s}; i) \pi(t) - F.
\]
\[
V_{x \text{IRD}}(d_{\text{IRD}}, i) = d_{\text{IRD}}(s_x = 1) \Pi_{x \text{IRD}}(t, i, \hat{s}_x = 1) + d_{\text{IRD}}(s_x = 0) \Pi_{x \text{IRD}}(t, i, \hat{s}_x = 0).
\]
\[
V_{x \text{RJV}}(d_{\text{RJV}}, i) = d_{\text{RJV}}(s_x = 1, s_y = 1) \Pi_{x \text{RJV}}(t, i, \hat{s}_x = 1, \hat{s}_y = 1) + d_{\text{RJV}}(s_x = 1, s_y = 0) \Pi_{x \text{RJV}}(t, i, \hat{s}_x = 1, \hat{s}_y = 0).
\]

Firms’ Beliefs

1. Following Bayes rule, the firm’s beliefs in the IRD are:
\[
\mu(s_x = 1 \mid \hat{s}_x = 1 ; i) = \frac{1}{l + q(i)}, \quad \mu(s_x = 0 \mid \hat{s}_x = 1 ; i) = \frac{q(i)}{l + q(i)}.
\]
2. If there is a positive level of influence activity, all information sets are reached in equilibrium and firms’ beliefs in the RJV are formed according to Bayes rule:

2.1 If \((s_x = 1, s_y = 1)\) is observed, beliefs are:

\[
\mu(s_x = 1, s_y = 1 | \hat{s}_x = 1, \hat{s}_y = 1; i, w) = \frac{w}{2q(i) + w(1 - q(i))^2}
\]

\[
\mu(s_x = 0, s_y = 1 | \hat{s}_x = 1, \hat{s}_y = 1; i, w) = \frac{1 - w}{2q(i) + w(1 - q(i))^2} = \mu(s_x = 1, s_y = 0 | \hat{s}_x = 1, \hat{s}_y = 1; i, w)
\]

\[
\mu(s_x = 0, s_y = 0 | \hat{s}_x = 1, \hat{s}_y = 1; i, w) = \frac{wq(i)}{2q(i) + w(1 - q(i))^2}
\]

2.2 If \((s_x = 1, s_y = 0)\) or \((s_x = 0, s_y = 1)\) is observed, beliefs are:

\[
\mu(s_x = 0, s_y = 1 | \hat{s}_x = 0, \hat{s}_y = 1; i, w) = \frac{1 - w}{1 - w(1 - q(i))} = \mu(s_x = 1, s_y = 0 | \hat{s}_x = 1, \hat{s}_y = 0; i, w)
\]

\[
\mu(s_x = 0, s_y = 0 | \hat{s}_x = 0, \hat{s}_y = 1; i, w) = \frac{q(i)w}{1 - w(1 - q(i))} = \mu(s_x = 0, s_y = 0 | \hat{s}_x = 1, \hat{s}_y = 0; i, w)
\]

2.3 If \((s_x = 0, s_y = 0)\) is observed, the firms believe with probability 1, that the true state is \((s_x = 0, s_y = 0)\).

Proof of Lemma 1:

\(w^*\) is defined as \(G(w^*) = \frac{I - w^*}{I - w^*(1 - q(i(w^*))} \pi \ (T - i(w^*)) = F\) \(G(w)\) is continuous in \(w\). \(i(w)\) is the optimal influence level of the researcher.

Note that \(G(1) = 0\) and \(G(0) = \pi(T) > F\).

It is easy to show that \(\frac{dG(w)}{dw} < 0\)

This implies that \(\exists w^*: 0 < w^* < 1\). \(\square\)

Proof of Proposition 3:

\((i^*, w^*)\) solve the following system of equations:

\[
(T - i)(1 - q(i))q'(i)w - (1 - (1 - q(i))^2)w = 0
\]

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\[
\frac{1 - w}{1 - (1 - q(i))w} \pi (T - i) = F
\]

It is easy to show that if the second order conditions for the researcher’s problem hold, that the sign of the determinant of this system is positive. Total differentiation of this system of equations gives that \( \text{sign} \frac{dw}{dF} = \text{sign} (\text{soc}) < 0 \), where \( \text{soc} \) is the second order condition for the researcher’s optimization problem.

**Proof of Proposition 4:**
Obvious comparative statics result from the first order conditions of the problem.

**Proof of Proposition 5:**
Case \( w \leq w^* \)
When substituting \( i^{\text{IRD}} \) into the first order condition for the RJV, we find after some manipulation:

\[
\frac{w}{2} \left[ 3 - 2q(i^{\text{IRD}}) - q(i^{\text{IRD}})^2 \right] - 1 = 0
\]

(P1)
Note that \( i^{\text{IRD}} \) does not depend on \( w \) and \( 0 < w < w^* < 1 \).
If \( 1 - 2q(i^{\text{IRD}}) - q(i^{\text{IRD}})^2 < 0 \), we can show that this expression is negative.
This obviously hold for \( w \) small.
Using the first order condition for the IRD:

\[
1 - 2q(i^{\text{IRD}}) - q(i^{\text{IRD}})^2 = 1 - q(i^{\text{IRD}}) - (1 - i)q'(i^{\text{IRD}})q(i^{\text{IRD}})
\]

We know from Assumption 2 that this expression is negative for all \( i \).
Now given that the second order conditions on the problem hold and (P1) is negative, we conclude that \( i^{\text{RJV}} < i^{\text{IRD}} \).

Case \( w > w^* \)
After substitution of \( i^{\text{IRD}} \) into the appropriate first order condition for the RJV and after similar manipulations as in the previous case, we get:

\[
1 + \frac{w}{2} \left[ 3q(i^{\text{IRD}}) - 2q(i^{\text{IRD}}) - 1 \right] = 1 + \frac{w}{2} (q - 1) \left( q + \frac{1}{3} \right)
\]

(P2)
The quadratic reaches its minimum at 1/3 at a value of -10/9.
Since \( 0 < w^* < w < 1 \), (P2) is always positive.
This, together with the second order conditions, imply that \( i^{\text{IRD}} < i^{\text{RJV}} \).

**Proof of Proposition 6:**
The expected profits of firm x in the IRD are:

\[
\frac{\pi_{\text{IRD}}(i^{\text{IRD}})}{2} - \frac{1 + q(i^{\text{IRD}})}{2} F
\]
The expected profits of firm x in the RJV are:

\[
\frac{L - (1 - \gamma)w}{2} \pi \left( t^{vo} \right) - \frac{I + q(t^{vo})}{2} F
\]

The profits of the RJV are strictly increasing in \( \gamma \).

Given that \( i^{IRD} > i^{RJV} \) from Proposition 5, the result follows immediately.

**Appendix 2: Example**

To illustrate the model and its results we develop the following example:

The firm profits, conditional on the signal are defined as: \( \pi(t) = 1 + t \). The continuation costs for the project are \( F = .50 \). Assumption 1 is satisfied for this profit function if \( \epsilon = 0 \) and \( \gamma = 1 \). As a reference point note that without any influence activity, the expected profit of the firm is .75. This is the best the firm could ever hope to do.

The researcher's private benefit is: \( b(T - i) = T - i \), and \( T = 1 \). To characterize the effect of influence activity, we consider the following class of functions: \( q(i) = i^\alpha \).

Assumption 2 is satisfied for this class of functions, where \( 0 < \alpha < .32 \).

**Case 1: \( \alpha = .1 \)**

In the IRD project the researcher invests \( i^{IRD} = .04035 \) in influence activity. The expected profits of the firm from organizing the project internally are: \( V^{IRD}(i^*, d^*) = .5485 \).

In the RJV the results depend on the correlation of the signals, \( w \), between the partners. The critical correlation is \( w^* = .8154 \). Figure 1A illustrates how this critical correlation is found through its dependence on \( F \). Increasing \( F \), decreases \( w^* \). Figures 2A and 3A illustrate the amount of influence activity by the researcher and the expected profits of firm x for both organizational structures. For example, if correlation is \( w = .5 \), the researcher spends \( i^{RJV} = .0117 \) time in influence activities and the expected profits of
organizing the research project in a joint venture is $V^{RJV}(i^*, d^*) = .5838$. The level of influence activity is increasing in the correlation level for $w < w^*$. Clearly the firm prefers the RJV to the IRD project when correlation between signals is low. If correlation is high, the result depends on the correlation level. For example, if $w = .85$, the researcher invests $i^{RJV} = .0724$ of her time in influencing the continuation decision. As a result expected profits are $V^{RJV}(i^*, d^*) = .5345$. In this case, the firm would prefer to perform the project internally. For the correlation close to one, the firm will again prefer to organize the project as a RJV. For example, if $w = .95$, the firm invests $i^{RJV} = .07$ time in influence activity. The resulting profits of the firm are $V^{RJV}(i^*, d^*) = .5575$. Note that influence activity is decreasing in the correlation level for $w > w^*$.

Case 2: $\alpha = .25$

In the IRD project the researcher invests $i^{IRD} = .0798$ in influence activity. The expected profits of the firm from organizing the project internally are: $V^{IRD}(i^*, d^*) = .57719$. The results are shown in Figures 4A through 6A.

In the RJV, the results again depend on the correlation of the signals, $w$, between the partners. The critical correlation is $w^* = .85536$. For example, if correlation is $w = .5$, the researcher now spends $i^{RJV} = .0322$ time in influence activities and the expected profits of organizing the research project in a joint venture is $V^{RJV}(i^*, d^*) = .628$. The level of influence activity is increasing in the correlation level for $w < w^*$. Clearly the firm prefers the RJV to the IRD project when correlation between signals is low. If correlation is high, the result depends on the correlation level. For example, if $w = .9$, the researcher invests $i^{RJV} = .1232$ of her time in influencing the continuation decision. As a result
expected profits are $V_{RJV}^{(i^*, d^*)} = .567$. In this case the firm would prefer to perform the project internally. However, if $w = .95$, expected profits are $V_{RJV}^{(i^*, d^*)} = .588$, and the firm prefers to organize a RJV for high correlation levels. Again, note that influence activity is decreasing in the correlation level for $w > w^*$. 

References


Scott, J., 1988, Diversification versus Co-operation in R&D Investment, Managerial and Decision Economics, 9, p.175-186.


Endnotes

1 Schilit and Loche (1982) classify the different methods of influence that have been studied into nine categories: logical or rational presentation of ideas; informal or non-performance specific exchange; formal exchange; adherence to rules; upward appeal; threats or sanctions; manipulation; formation of coalitions; persistence or assertiveness. Allen et al (1979) report that in their sample of 87 managerial personnel the “use of information” was the single most mentioned tactic of influence activity. The tactic of withholding and distorting information could be extremely dysfunctional from an organization’s perspective.

2 Usually, one partner will set the price of shares and the other has the option to buy that partner’s shares or sell his own shares to the partner for that price.

3 Having control rights over the project allows that party to intervene during the project and take actions that are not contractible, but increase the value of the project to that firm. The only rights that ownership conveys to the party that does not have control is a veto right to certain actions and certain rights when the partnership is dissolved. We will not explicitly model any decision over these non-contractible actions, but we assume that each firm weakly prefers to have control over the project. See Aghion and Bolton (1992) for an explicit model.

4 We assume that firm x cannot sell the right to join the RJV to firm y to extract the value of the RJV to firm y and create any intrinsic value of the RJV over the IRD. Alternatively we could assume that the expected NPV of the project to firm y (and firm x under symmetry) is zero. Ownership in a research joint venture is often determined by the initial investment. In the model, we concentrate on the continuation decision of the project. The initial investment is sunk at that time.

5 Because these benefits are not transferable, influence activity and the distribution of rents become an important issue (Milgrom and Roberts (1992)).
Given that the allocation of effort by the researcher is unobservable and given his specific investment into the project, the researcher always has an incentive to influence the signal if not fully compensated for the expected rents related to this investment. This compensation, however, might introduce other distortions in the effort choice of the researcher, especially if the researcher could also influence the signal in the negative direction.

Note that we could consider the choice of the IRD versus the RJV as a choice over information structures. In the IRD, the set of partitions of the information structure are \( P_S = \{ ((1, 1), (1, 0)), ((0, 1), (0, 0)) \} \). Firm x only observes whether its signal is high or low. In the RJV the set of partitions of the information structure is \( P_S = \{ ((1, 1)), ((1, 0)), ((0, 1)), ((0, 0)) \} \). The choice of the IRD over the RJV implies the commitment to a coarser information structure.

The model could be extended to a continuum of signals for an individual firm. The intuition derived from this discrete model would not be changed. However, a model with a continuum of signals does not allow us to separate the issues of cost sharing and flexibility as transparently as in the discrete model. Also, the modeling of the effects of influence activity by the researcher would be more involved without adding any intuition.

The model implicitly assumes that influence activities by the researcher do not reveal any useful information for the continuation decision of the project. The true signal incorporates all this information. The only cost of influence activities to the researcher is its opportunity cost of not spending time on productive activities which increase the researcher’s expected private benefits, conditional on continuation.

The assumption of independence implies that whether influence activity by the researcher is successful at manipulating the signal of both firms does not depend directly on the correlation of the signals. We find this a reasonable starting assumption. We will come back to this assumption when discussing the results.
An alternative model that includes an explicit cost of influence activity, might assume that in an RJV the researcher would have to lobby two decision makers. This increases the marginal cost of influence activity (possibly as a function of the correlation between signals). As a result we expect less lobbying activity in the RJV compared to the IRD. The qualitative results of such a set up would be very similar. I would like to thank Scott Schaefer for suggesting this alternative formulation.

See Appendix 1 for the conditional probabilities.

This result could be made even stronger when the reduced research effort in the preliminary phase could lead to the termination of a potentially good project. The assumptions of the model do not allow for this case to occur (see Assumption 1.1).

We need to check that the firm does not want to commit to continue the project when the signal is low. The firm could just disregard the signal and always continue the project. We assume that any contract that would continue the project with some probability after the low signal, is infeasible. This strategy would not be renegotiation proof. In what follows we assume that it is never profitable for a single firm to make this type of commitment. In the extensions we will come back to this assumption.

Note that Assumption 2 guarantees a unique interior solution to the researcher’s problem.

Firm y makes firm x a take-it-or-leave-it offer for zero, which firm x accepts given that it does not value the project.

Again, Assumption 2 guarantees an interior solution to the researcher’s maximization problem.

Note that at \( w^* \), the level of influence activity with the continuation policy defined in (2), is lower than with the continuation policy defined in (3). This implies that at \( w^* \), due to Proposition 2, the firms’ policy is to continue the project for all signals except when both firms observe a low signal.
There does not exist a mixed strategy equilibrium of the game at \( w = w^* \). Given the concavity of the researcher’s problem, the researcher has a unique pure strategy influence level, regardless of the continuation decision by the firms. Suppose that at \( w = w^* \), the firm making the continuation decision is indifferent between continuation or not. Any mixed strategy on the part of the decision maker would increase the amount of influence activity by the researcher. Thus it must be the case that Condition (1) is also violated for any mixed strategy at \( w^* \) so that the firm cannot be indifferent.

This result seems to suggest that firm x should look for a partner with a signal that is perfectly negatively correlated \((w=0)\). Low correlation of the signals does not imply that the firms are necessarily distant in terms of their technology employed. In what follows, we will argue that this correlation is related to the nature of research performed, i.e basic versus applied (see below). In order to relax this result somewhat we could introduce a probability of success for projects. Projects with lower correlation of the signals would imply lower expected success rates.

Although we did not assume any direct effect of correlation on influence activity (see before), we find that in equilibrium correlation does have an indirect effect on the level of influence activity in the RJV through the continuation decision.

We could extend the model to allow the level of future competition, \( \gamma \), to depend on the correlation. We would expect that competition becomes more intense as the correlation between the partners’ signals increases: \( \gamma(w) \) is decreasing in \( w \). This leads to a result that favors the formation of more IRDs relative to RJVs since it increases the first term in the expression.

For example, Collins and Doorley (1990) find in their study of the VLSI project in Japan that “there was a clear split between fundamental research carried out within the joint laboratories and more applied work undertaken with the companies themselves.”
Union Miniere, a Belgian multinational with a focus on non-precious metals, has the policy that a research project at the central R&D lab can have several business units as a partner, but only one of the business units will actually fund the project.

It can be shown that for this example, the RJV always dominates the IRD for correlation levels in a neighborhood of 1, except if $\alpha = 0$. In that case the IRD and RJV are equivalent for $w = 1$ and the RJV is strictly worse for any $w < 1$. 

\[ \text{RJV always dominates IRD for correlation levels in a neighborhood of 1, except if } \alpha = 0. \]