

# Building Competitive Advantage through Links with Science

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**ABSTRACT:** “It is hard to imagine a more significant topic in today’s economy than inter organizational technology” (Stuart, 2005). And indeed there is mounting evidence pointing to the fact that firms’ innovation process is increasingly involving partners beyond their boundaries, including research organizations, business partners, and universities (Chesbrough, 2003; Laursen & Salter, 2006). In particular, the organizational agreements between business firms and universities have recently come to the forefront of research.

## I.INTRODUCTION

Engaging in links with universities has been repeatedly shown to contribute to firms’ competitive advantage. In a sample of 77 major firms, Mansfield (1998) finds that innovations that could not have been developed without substantial delay in the absence of recent academic research account for over 5% of the total sales of all major firms. More generally, the 2001 U.K. Community Innovation Survey indicates that those firms that use universities as a partner exhibit better results in terms of increased range and quality of goods and services, increased market share, and reduction of labor costs as compared to firms that do not rely upon universities in their R&D process. George et al. (2002), analyzing 2457 alliances undertaken by 147 biotechnology firms, show that companies with university linkages display a more efficient R&D process, having lower R&D expenses and a higher innovative output. And Belderbos et al. (2004) provide evidence that cooperating with universities leads to a higher growth in sales of ‘new to the market’ products. However, two issues still remain largely unsettled: first, why would have links with enhance business performance? And second, how should these links be organized so that they perform best?

Prior research has explored which firms are more likely to establish links with universities. Firm size and R&D intensity are usually reliable predictors of the propensity to establish links with university (Mohnen & Hoareau, 2003; Adams et al.,2003), though these results pretty much resemble those of the studies on R&D cooperation in general (Hagedoom et al., 2000). Cassiman and Veugelers (2002) find the lack of appropriability concerns to be a significant difference, yet it is not clear whether this is a firm-specific ‘predetermined attitude’, or rather something that characterizes the relationship with universities which then influence firms’ perception.

In parallel with the above mentioned studies, other papers have explored the specific reason that drives firms to establish links with universities. Hall et al. (2000) identify two broad motivations: access to complementary research activities and access to key university personnel. Cost and risk sharing are additional important drivers for cooperative agreements, as in early stage research financial barriers to innovation may be strong given the imperfection of financial markets (Miotti & Sachwald, 2003; Veugelers & Cassiman, 2005). Fleming and Sorensen (2004), conceptualizing invention as a combinatorial search process, argue that science alters inventors’ search processes, by leading them more directly to useful combinations, eliminating fruitless paths of research, and motivating them to continue even in the face of negative feedback. Moreover, through the collaboration with academic scientists firms may also develop their absorptive capacity (Markiewicz, 2004). Accordingly, Cassiman and Veugelers (2006) find that relying on universities and research centers as an information source is an important contextual variable affecting the complementarity between internal and external innovation activities. Therefore, links with universities increase the productivity of the innovation process that combines internal and external knowledge sources.

However, little is known on the actual organization of the linkages between business firms and universities, i.e. the how of these links. To begin with, engaging in ‘linkages’ with universities, a terminology adopted by the majority of prior – survey based – research, may surely mean a number of different things, ranging from collaborative research to technology licensing from universities, from university consultancy to continuing education programs. We believe that a clear disentanglement is needed to advance our knowledge of industry-science links and their potential contribution to competitive advantage. In this study, we decided to focus on the formal organizational linkages (i.e. contracting cooperative agreements) between business firms and universities, adopting the R&D project as the unit of analysis.

The project – level analysis of the factors affecting the organization of formal links with the university is therefore an important contribution of our paper. While prior literature has deeply scrutinized which factors at the industry and at the firm level have an impact on the organization of firms' R&D activities (e.g. Pisano, 1990), little attention has been devoted to the significance of the specific attributes of the R&D activities (i.e. R&D projects) themselves. Theoretical models (Aghion et al., 2005; Lecetera, 2005) suggest that a project's length, uncertainty, and degree of overlap between scientific and commercial value are crucial variables determining firms' propensity to outsource the project to universities or research centers. Yet the empirical evidence on this issue is scant at best. In addition, earlier literature on R&D projects has seldom analyzed hybrid forms of governance, that is, cooperation, as an alternative to contracting. And even in this case, it has often reasoned as if projects should be either fully developed internally or fully contracted out, ignoring the frequent case in which only a fraction of a project is developed through external sourcing.

Besides the actual organization of industry-science links, also their economic effects have been scarcely explored by previous literature, i.e. the why (Hall et al., 2003). In particular, while there is some evidence that establishing links with universities may enhance firms' performance (e.g. Mansfield, 1998; Belderbos et al., 2004); it is not clear the process through which this effect can take place. In particular, an obvious remark could be raised: if collaborating with the university is so good for innovation performance, why is not everybody doing it? A first answer could be that the direction of causality between partnerships with universities and performance may be unclear. The propensity to engage in R&D agreements may well be a function of prior performance: Stuart (1998) has found that firms with a track record of developing seminal inventions form alliances at a higher rate. The same phenomenon could hold also for the agreements with universities. Yet, while Stuart justifies his findings through firms' prestige, which augments the demand of potential partners, it is still not clear why well performing companies would establish links with universities if that was not beneficial. Moreover, there seem to be substantial differences in firms' ability to tap into external scientific knowledge and cooperate with scientists (Cockburn & Henderson, 1998), indicating the need for a careful analysis at the project level.

A second possible explanation is that, since performing in-house basic R&D can constitute a source of competitive advantage in high-tech industries (Gambardella, 1992), having links with universities is simply correlated with the internal execution of basic research, and thus has a spurious (or at least indirect) effect on business performance. However, even though over the last thirty years there has been a substantial increase in formal relationships between companies and universities, the majority of firms still perform the bulk of their R&D activity with their boundaries, even in high-tech industries (NSF, 2002). Furthermore, Cockburn and Henderson (1998) argue that firms wishing to take advantage of public sector research must do more than simply invest in in-house basic research: they must also actively engage in establishing links with their university colleagues. We are thus still left with our initial question: why would having links with universities increase firms' efficiency and enhance their performance? Therefore, a second key contribution of our paper is thus an exploration of this process through the analysis of the performance effects of formal linkages with universities, again at the project level. Only at this level can we adequately control for the characteristic of the projects and activities that are performed across firm boundaries.

We expect that on average firms choose their strategies rationally by choosing the strategy those results in the greatest expected return. If we observe some firms choosing one strategy and other firms choosing different strategies, we should not expect that one strategy unconditionally leads to superior – or inferior – results in terms of performance. Failure to account econometrically for this endogeneity in strategic choices can significantly bias the results of the analysis (Shaver, 1998). Previous research that posits a positive relationship between firms' performance and links with universities may therefore have omitted relevant variables for lack of knowledge of the factors driving firms' strategic choices and the success of industry-science links. Our study allows gaining some more insight into corporate behavior also in this respect.

In summary, we find that the attributes of the knowledge involved in R&D projects affect significantly their organization. Partnering with universities is common practice for developing new – original – knowledge as opposed to applying existing knowledge to a problem. But the firm is more reluctant to partner when this knowledge directly enhances its competitiveness. Contracting for innovation to universities, as opposed to partnering, happens for more experimental projects, where very original knowledge is developed, and typically early on in the project. To decrease the cost of communication, even at the risk of making new knowledge more easily stolen, more tacit projects are carried out internally and more codified ones is partnership we also find that project managers appreciate two dimensions of project performance – efficiency and learning – though our results suggest that universities are sought mainly for efficiency in that learning is not (immediately) observable and contractible. If project managers are purely rewarded on the basis of efficiency, those learning will necessarily be overlooked.

The paper proceeds as follows. First, we describe our research design. Given the more exploratory nature of this study, we rely upon extremely rich and fine-grained data collected by studying the case of a subsidiary of a major multinational. Next, drawing upon the transaction costs economics and the resource based view of the firm literature, we

discuss the possible determinants of R&D projects' organization. We then move to the description of our empirical findings and conclude by discussing their implications for research.

## II. EMPIRICAL STUDY: METHODS

### Research setting

In the quest for new and more insightful empirical evidence on the theory of organizations, Williamson (1991) concedes there is merit in shifting the emphasis away from the best generic institutional form for organizing a particular transaction, to the best way for a specific firm to organize this transaction. Accordingly, our study is based on the case of a subsidiary of STMicroelectronics (ST). ST is a global company based in Geneva and is the fourth largest producer of microelectronic components in the world, according to the ranking issued by Gartner Dataquest (2003). The group has currently more than 45,000 employees, 16 advanced R&D units, 17 main manufacturing sites, and 88 sales offices in 31 countries. Our analysis focuses on an ST subsidiary which distinguishes itself worldwide for its research focus and the large amount of resources allocated to R&D<sup>2</sup>.

This represents an especially attractive setting to study innovation strategy and the governance of R&D projects. First, the semiconductor industry is a fast-moving, high-tech industry where R&D plays a fundamental role in competition. The impulse toward technological innovation given by nanotechnology and the opening of new application fields together with the global dimensions of the market and competitors, make this sector highly dynamic and competitive. And second, a key contribution to ST's success has been its 'open' innovation process. This includes strategic alliances with key customers, technology development alliances with both customers and competitors, development alliances with major equipment, materials and CAD suppliers, and partnership with multinational R&D organizations, universities, and research institutes.

### Data and measurement issues

With the help of industry experts, we collected fine-grained data at the project level, developing a database that contains 52 R&D projects that started between 1998 and 2002. More specifically, our sample comprises all the R&D projects for which the ST subsidiary we considered has asked some form of external financing in this time-frame. Not only did we collect data at the project level, but we were also to deepen the structure of the project. Each project is in fact composed by a number of individual activities, which get started sequentially. For each activity, besides technical information and organizational information, we know whether the activity at stake is devoted to develop and acquire new knowledge, vis-à-vis the application and the achievement of concrete results from knowledge previously developed or acquired. All the available information concerning the project is reported in the application for external financing.

Not all R&D projects are alike. Accordingly, we should expect their governance forms to differ. Nonetheless, we know surprisingly little on this matter. Which project characteristic have an influence on the organizational design? The next issue we tackled in our research design was therefore that of deciding which R&D project attributes to consider relevant in determining their organizational design. In this paper, we will contend that the knowledge characteristics of R&D projects are fundamental variables to explain government decisions. Over the last two decades, as a firm's competitive advantage is now more dependent on continuous knowledge development and enhancement, knowledge has become a central theme in strategic management (Grant, 1996; Spender, 1996). While knowledge has been defined in a variety of ways (e.g. Hedland, 1994; Nonaka & Takeuchi, 1995; Spender, 1996), it has been shown to be an important contingent variable influencing organizational design in different technological setting (Brikshaw, Nobel, & Ridderstrale, 2002; Zander & Kogut, 1995), and firm's R&D strategy depends on the characteristics of the productive knowledge on which they are based and the means that are effective in protecting knowledge assets (Winter, 1997). We thus collected indicators of R&D projects' knowledge attributes.

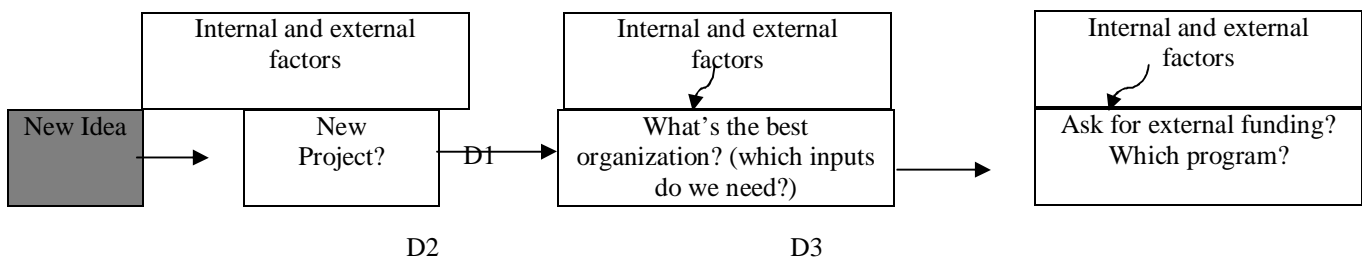
Each project for which external funding is asked is evaluated and characterized with respect to its knowledge content by the applicants. First, the novelty and characterized with respect to its knowledge content by the applicants. First, the novelty and originality of the knowledge developed in the project as compared to the firm's technological domain in evaluated on a 1 to 3 scale. Second, again on a 1-to-3 scale, the relevance of the knowledge developed to achieve product or process innovations that can enhance the competitiveness of the firm is assessed. This measure clearly relates to the strategic value of the project. And third, on an 1-to-4 scale, the ease of industrialization and of transferability to manufacturing of the outcomes of the project is evaluated. This measure can be used as a proxy of the relative codification of project's knowledge (Grant & Gregory, 1997). We constructed a measure considering the percentage of projects' activities with the goal of developing new knowledge (as opposed to applying it), which can constitute an indicator of the basicness of the project. Finally, we also collected objective project measures, like total cost and length.

Measuring intangible variables is arguably the main difficulty in empirical research on transaction costs as well as in the capabilities approach (Shelanski & Klein, 1995). While our measures may contain a certain degree of subjectivity, they are still reasonably valid and reliable. First, the application for external public financing for industrial R&D projects is a complex process. We interviewed three R&D division directors, a project manager, the responsible of the department for

external R&D contracts and the persons in charge of two of the most frequent “science” research partners of ST: all of our interviewees – whether belonging to ST or public research institutes – consistently acknowledged this fact. The process requires a deep technical knowledge as well as a sound understanding of the regulatory context. All the applications must contain some common and comparable, quantitative and qualitative projects characteristics. Furthermore, all the applications are reviewed by independent experts nominated by the funding organization in a competitive process in which several applicants are denied financing. Misrepresenting the characteristics of the project is easily detected by the reviewers, with the consequence of drastically decreasing the chances of being financed and harming the firm’s reputation. Second, financing applications – and thus knowledge attributes evaluations – have been compiled by the same team of experts over the four years under scrutiny. The team is not involved directly in the decision regarding projects organization. These circumstances, the cross-check of measures of highly qualified observers, made for entirely different purposes than those of our study, increase the validity of the measures at stake (king, Keohane, & Verba, 1994). Two additional important issues are to be stressed. First, the subsidiary under scrutiny generally asks external financing for the great majority of its research projects, ruling out – or at least reducing significantly – one possible source of selection bias. Second, the request for external financial support does not alter the organization of the projects. Our interviews highlight that the optimal organizational form is decided *ex ante*. And then, and only then, the most appropriate financing program is searched program to apply to, given the project characteristics and organization. What really matters is to which funding program to apply to, given the project’s features. Thus, we believe that no systematic bias affects our measures. Figure 1 reports the sequence of decisions ST adopts. Our empirical analysis refer to decision D2 and it is based on the projects for which decision D3 has been affirmative, i.e. they requested financing, but did not necessarily receive it.

Eventually, firms are concerned about performance. The next natural step in our analysis was therefore identification of the consequences of different organizational forms on performance. We thus gathered data on the performance of 39 out of 52 projects (those that were already completed or close to completion) through a short questionnaire administered to the project managers. The questions are based on the items of the scale developed by Sicotte and Langley (2000) and Hall et al. (2003) to assess R&D projects performance. More specifically, on a 1-t0-7 Likert scale, project managers were asked to evaluate the extent to which : (a) the technical outcome of the project has met expectations, (b) the project has respected the schedule, (c) the tasks have been accomplished, (d) the project is on or near budget, (e) the project on the whole has outperformed similar projects they carried out in the past, (f) potential new applications of the technology / outcome being developed have been recognized over the course of the project, and (g) in the project they have acquired knowledge that they already applied or are confident they will apply in other projects.

**R&D projects decision sequence.**



**III.PROJECT ATTRIBUTES AND ORGANIZATION**

Having described our research setting and the variables of interest, we now turn to a brief discussion of how these variables could influence R&D projects’ organizations.

In this paper, we will assume that three main possible organizational forms may be adopted: internal development, cooperation, and contracting (Williamson, 1991). The three organizational forms vary in terms of the firm’s control and ownership of results as well as in terms of firm’s ability and flexibility to respond to unanticipated circumstances. At the same time, they also vary in their ability to tap into external resources and capabilities. The organization of R&D projects should thus depend on the alignment between characteristics, organizational forms’ characteristics, as well as on internal and potential partners’ capabilities portfolio (Madhok, 2002.).

We contend that four important dimensions of the knowledge involved in R&D projects may affect their organization. A first relevant dimension of a project’s knowledge is represented by its basicness, i.e. its relatedness to



fundamental research (Rosenberg, 1990). On one hand, the basicness of the project should favor the recourse to external sourcing. Since the seminal papers by Arrow (1962) and Nelson (1959), it has been recognized that firms may have scarce economic incentive for investments in basic research. Uncertainty about the results and appropriability hazards constitute two relevant causes for this lack of incentive. These same factors may also drive the failure of the market for knowledge. Cooperation in R&D may decrease the intensity of these obstacles. Firstly, by cooperating with universities firms may share risks and costs (Miotti & Sachwald, 2003; Veugelers & Cassiman, 2005). And secondly, cooperation may facilitate the internalization of knowledge spillovers (D'Aspremont & Jacqueline, 1988). Moreover, by way of cooperation firms may learn and build capabilities they would not get by simply contracting out their needs (Hagedoorn & Schakenraad, 1994). Universities and research centers should be better able to leverage their capabilities in basic research, given that their efforts are traditionally oriented towards it, and should thus constitute a preferred partner (Dasgupta & David, 1994).

The novelty of project's knowledge relative to the firm's existing knowledge base represents a second important dimension (Abernathy & Clark, 1985). Novelty increase the propensity to cross firm's boundaries when organizing the project. Firms are more likely to look for complementary external resources when they are moving away from their knowledge domain (Sakakibara, 2001), looking for partners with more productive resources given a specific task (Korus & Zander, 1992). However, this could be true only up to a certain point. Received theory argues that when melting different knowledge bases, some knowledge relatedness is needed in order to benefit from absorptive capacity (Cohen & Levinthal, 1990), but also that if knowledge bases are too similar as well as too different, then there is no room for valuable external contributions to innovation (Ahuja & Katila, 2001).

However, the higher the basicness and the novelty of a project, the higher its uncertainty. Therefore, internal development could provide a better means to respond to unanticipated contingencies (or opportunities) over the course of the project (Oxley, 1997). While technically novel projects need creative problem solving, they may also cause unwanted delays and cost overruns (i.e. increase outcome uncertainty): hierarchical governance may be needed to guard against these hazards (Ulset, 1996). Also, internal development relieves firms from fully specifying contractual arrangements, whose terms are less obvious and known when information is new and uncertain (Williamson, 1991). In addition, the more basic and novel the project, the lower the ability to assess its outcomes. Uncertainty on performance measurement creates a higher incentive for opportunistic behavior of partners, and thus should make more likely internal development (Robertson & Gatignon, 1998).

Contractual hazards and the incentive of the external factors involved in an R&D project to behave opportunistically are higher when the expected pay-off of such behavior is higher. The expected pay-off depends both on (a) the intrinsic potential value of the results of the project and on (b) the probability of being able to capture the value itself. These, in turn, depend on two important projects' knowledge dimensions: strategic importance and modifiability. Projects whose knowledge is of relevant strategic value may increase the incentive for partners to cheat and perhaps engage in a 'learning race' and avoid sharing the developed knowledge (Hamel, 1991). In addition, projects of strategic importance more often imply commitments and specific investments (Ghemawat, 1991). The more specialized a resources, the lower its value in alternative uses, and the higher the probability of being held-up by a partner. Therefore, internal development should be preferred (Robertson & Gatignon, 1998; Williamson, 1985). Nonetheless, it is in highly strategic projects that it becomes evident how no single firm has all the capabilities necessary for success (Powell, 1990). As firms might lack competence in a number of technological fields, cooperation with universities creates the necessary complementary inputs and enables to capitalize on economies of scope and limiting potentially opportunistic behavior as universities have lower commercial incentives.

Finally, the extent to which the knowledge of a project is modifiable, as opposed to tacit, constitutes the fourth relevant knowledge dimension. The sources and significance for organizations of this dimension of knowledge are explored in depth in Nelson and Winter (1982). When a project's knowledge is prevalently codified, it is easier to 'steal' project outcomes and partner's competencies (Zander & Kogut, 1995), thus making opportunistic behavior more probable (and consequently development through alliances less probable). Furthermore, Arrow (1974) contends that a key advantage of organizations is their ability to economize in communication through a common code. When the knowledge to be shared is tacit, the cost of communicating and coordinating with an external partner are higher, and thus internal organization is presumed to be more efficient (Kogut & Zander, 1992). But, at the same time tacit knowledge is more easily transmitted through close cooperation compared to a more arm's length relation in a contractual agreement.

#### IV. EMPIRICAL STUDY: FINDINGS

The projects included in our sample have an average length of 31.5 months and, on average, require 8.2 man-years to be completed. Seven different strategic lines of innovation may be explored: technological and design platforms; advanced application, new devices, and optoelectronic integrated circuits, memories and system on chip; nanotechnologies; new materials; bioelectronics, health; new computational models. Project ideas may have originated externally (in a

university as well as in a firm) or internally (in the same R&D division in which the projects are carried out, in another R&D division, at the subsidiary's central R&D, or at the corporate R&D unit). Projects may also have different intended clients, which may be internal and/or external. An analysis of the correlation matrix between projects' origin and clients (which is not reported here, but available upon request from the authors), highlights the following results. First, the only 'originator' that has a strong correlation with the fact of being also a client of the same project is central R&D ( $r = 0.70$ ). Second, projects that originate from a university are positively correlated to having corporate R&D as their client ( $r = 0.40$ ). This is consistent with the stylized fact that corporate R&D is generally closer to science (Hauser, 1998). Third, projects that originated in the same R&D division where they are carried out are negatively correlated to having a customer external to the firm ( $r = -0.51$ ). Units' autonomous projects seem thus to be scarcely market oriented. And four, as could be expected, projects that originated outside ST are positively correlated to having external clients ( $r=0.53$ ).

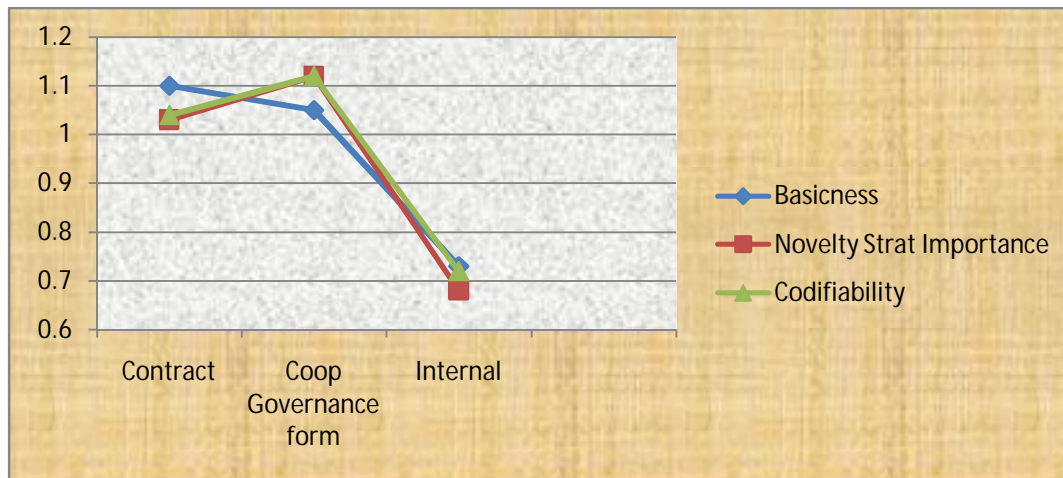
Only 9 out of the 52 projects do not involve universities. This confirms that not only do firms need informal links with universities and academic scientists, but they also need to establish formal link with them (Cockburn & Henderson, 1998). ST researchers do have daily contacts with universities, attend academic conferences, and regularly read scientific literature. Nonetheless, they consistently form formal linkages with universities.

### The determinants of projects' organization

In this study, we focused on three possible organizational forms: internal development, cooperation with a third party, and contracting out. Contracting implies that a partner commits to deliver a contractually specified output for some activities in the project. Cooperation represents an intermediate – non market, bilateral – hybrid governance mechanism between market and hierarchies, where both parties are jointly responsible for the project outcome. As said, Williamson (199

1) and several other scholars depict alliances as a hybrid forms of governance lying in the middle of a continuum that ranges from internal development to contracting. In Gomes-Casseres (1996:35) words: "Alliances... involve a mix of features of firms and markets. They resemble markets in that the partners remain separate parties, driven by their own interests. Each partner thus runs some risk that the other will act opportunistically, as traders might in the open market. Alliances resemble firms in that the partners agree to coordinate their actions and participate in joint decision-making. "More specifically, transaction costs economics assumes that, due to economies of specialization and the administrative and incentives limit of hierarchies, markets are a more efficient structure, unless transactions are surrounded by special circumstances that increase transaction costs (Williamson 1975; 1985). Cooperative agreements lie somewhere in between market and hierarchies, and are expected to be chosen when transaction costs concerns are, so to say, intermediate.

Yet our field research provides somehow mixed evidence on the drivers of organizational agreements with universities in this respect. Not all the variables clearly follow the 'monotone path' suggested by the continuum hypothesis. Table 1 reports the average value of some projects' characteristic for different organizational forms involving – or not – universities and research centers. Figure 2 reports the ratio between the average values of knowledge attributes across organizational forms and the sample average of the same attributes. It appears evidence that, the more basic a project – i.e., the more devoted it is to create new knowledge as opposed to apply it – the more the firm relies upon university's abilities, and it does so adopting predominantly a cooperative behavior. Establishing formal cooperative agreements (as opposed to contracting out activities) allows not only sharing risks and costs, but it also favors the development of new capabilities through inter-organizational learning (Colombo, 2003). Partially contradicting what Veugelers and Cassiman (2005) had found at the firm level, appropriability concerns may limit the firm's propensity to cooperate at the project level, even with universities. The strategic importance of R&D projects dissuades cooperation. However, in highly strategic projects, some activities are frequently contracted out to universities. Both the organizational form and the partner's features mitigate the risk of opportunistic behavior.



Projects' knowledge attributes and university involvement.

		Contract	
		0	1
Cooperation	0	No. of projects: 9 project cost: 8 % of %of cost for st:0.81 basicness: 0.55 novelty: 1.44 strategic importance:2.1 codifiability: 1.7	no of projects: 21 project cost: 12.05 % of cost for st: 0.86 basicness: 0.83 novelty: 2.14 strategic importance: 2.57 codifiability: 2.4
	1	no. of projects: 14 project cost: 7.85 % of cost for st: 0.52 basicness: 0.90 novelty: 1.93 strategic importance:1.92 codifiability: 2.6	no of projects : 8 project cost: 9.6 % of cost for st: 0.60 basicness: 0.95 novelty: 2.38 strategic importance: 2.37 codifiability: 3
		no. of projects: 23 project cost: 7.9 % of cost for st: 0.63 basicness: 0.76 novelty: 1.74 strategic importance: 2 codifiability: 2.2	no of projects : 29 project cost: 11.4 % of cost for st: 0.80 basicness: 0.86 novelty: 2.2 strategic importance: 2.52 codifiability: 2.55

The same pattern is observable with respect to the novelty of the knowledge involved in the project; in highly novel projects the firm tends to contract some of the activities out, yet these projects are less likely to be conducted in cooperation. To decrease the cost of communication, even at the risk of making new knowledge more easily stolen, more tacit projects are carried out internally and more codified ones in partnership. Finally, consistent with prior literature

(Veugelers & Cassiman, 2005), we do find that sharing costs is an important driver of cooperation with universities. The qualitative results of simple means comparisons are broadly supported by more sophisticated analyses.

Table 2 reports the results of a logistic regression aimed at estimating the drivers of cooperation with universities. The parameter estimate for the basicness of the project is positive and significant ( $p < 0.05$ ), indicating that the more activities are dedicated to develop knowledge (as opposed to apply it), the more likely the project is carried out in partnership with a university. Conversely, the parameter estimate of a project strategic importance has negative sign ( $p < 0.1$ ). As predicted by TCE, potential project value may increase the likelihood of opportunistic behavior and therefore discourage cooperation.

However, the propensity to cooperate with universities may be merely driven by the “origin” of the project, i.e. the origin of the innovative idea that eventually led to the R&D project under scrutiny. Potentially, if the idea originated at the university itself, this could imply a higher basicness of the project as well as a higher propensity of ST to cooperate with this institution. Specification (2) includes dummy variables for the projects’ origin and prior results are confirmed. Finally, the propensity to cooperate with the university may also depend on the specific strategic innovation line the project belongs to: specification (3) includes the dummies for innovation lines, and our initial results remain robust. Though our reconstruction of the decision process highlights that the request for external financing does not influence the organization of the process, we also estimated a specification that includes dummies for financing programs. The results – not reported here – are in accordance with those of our basic specification.

In the prior analyses, we treated each project organization decision as if it were independent from the others. Yet these decisions have been taken at different moments in time, and may be contingent upon prior decisions. For instance, prior cooperation’s with a partner may make future cooperation more likely (Gulati, 1995). While the relatively low number of observations and the fact the dataset is left – censored prevent a full econometric analysis, we nonetheless tried to explore this possibility. To this end, for each project we constructed a binary variable that takes the value of 1 if there exists at least one project within the same R&D unit that ended the same year or the year before that in which the focal project started, and which was carried out in cooperation with a university. This dummy thus captures the possibility that organizational decisions may depend on past organization structures. Results of logit regression including the variable are reported in table 3 and do not shows any relevant change in the parameter estimate our main covariates.

Table 4 reports the results of the logit regression assessing the factor driving the propensity to engage in R&D contracting with universities and research centers at the project level. The results confirm what has been described before: ST is likely to contract with universities or research centers in projects in which the knowledge involved is substantially novel ( $p < 0.01$ ) and whose application will lead to strategic results ( $p < 0.1$ ). R&D contracting of some activities appears as a useful mixed solution. Hierarchical control is helpful in preventing deviation from known courses to pre-specified outcomes, but it is not equally helpful in promoting the exploration of unknown courses toward innovative solutions. Although hierarchies have the advantage of more coordinated adaptation, they also have the disadvantage of weaker incentives due to risk reduction and the impossibility of selective interventions (Williamson, 1985). The parameter estimate of the project’s total cost is positive and significant ( $p < 0.1$ ). As projects with large research budgets often undertake research of a broader scope than that involved in lower budget projects (Hall et al, 2003), this result reinforce the idea that universities are sought in novel projects. Results do not show any effect of the project’s basicness on the propensity to engage in R&D contracting with university. As in our previous analyses, specification (2) includes the dummies for projects’ origin and specification (3) those for innovation lines. And again, results are generally robust to these different specifications. We also observed that the firm is more likely to contract to universities projects’ initial activities and those aimed at creating knowledge is the target of the activity itself.

Propensity to cooperate with universities or research centers considering priorities.

Constant	0.34 (2.40)
Project cost	-0.09 (0.07)
Basicness	5.60** (2.28)
Novelty	-0.64 (0.91)
Strategic importance	-1.26* (0.63)
Codifiability	-0.22 (0.38)
Prior cooperation with University	1.76 (1.17)
N of ob observations	52
$\chi^2$	18.85**

† $p < .10$  \*  $p < .05$  \*\*  $p < .01$  \*\*\*  $p < .001$  a Standard errors in parentheses



Propensity of R&D contracting with universities or research centres.<sup>a</sup>

	(1)	(2)	(3)
Constant	-10.54*** (3.11)	-10.10** (3.42)	-12.95** (4.85)
Project cost	0.15 (0.08)*	0.19* (0.08)	0.18* (0.08)
Basicness	-2.77 (2.11)	-2.91 (2.40)	-2.98 (2.11)
Novelty	2.83** (1.27)	2.98* (1.52)	3.22* (1.43)
Strategic importance	1.82* (0.73)	1.30 (0.85)	1.97* (0.87)
Codifiability	0.84† (0.43)	1.07* (0.54)	0.88 (0.49)
Origin = university			(b)
Origin = other firm			-2.11 (1.18)
Dummies for innovation			
Line included	No	No	Yes
N of observations	52	48	50
X <sup>2</sup>	27.12***	27.78***	28.76***

†p<.10 \*p<.05 \*\* p<.01 \*\*\* p<.001

<sup>a</sup> Standard errors in parentheses.

<sup>b</sup> Dropped because predicts success perfectly.

**Propensity to contract with a university in a given activity.<sup>a</sup>**

**Activity level variables**

Relative position	-0.51 ↑ (0.31)
Activity aimed at developing new Knowledge (dummy)	1.02*** (0.31)
Dummies for typology of activity	Included

**Project level variables**

Cost of the project	0.17*** (0.02)
Basicness	-1.78* (0.85)
Novelty	2.17*** (0.30)
Strategic importance	0.24 (0.25)
Codifiability	0.72*** (0.11)
Dummies for lines of innovation	Included
Dummies indicating origin of the Project	Included
N of observations	1123
X <sup>2</sup>	361***

† p<.10 \*p<.05 \*\* p<.01 \*\*\* p<.001

<sup>a</sup> standard errors in parentheses.

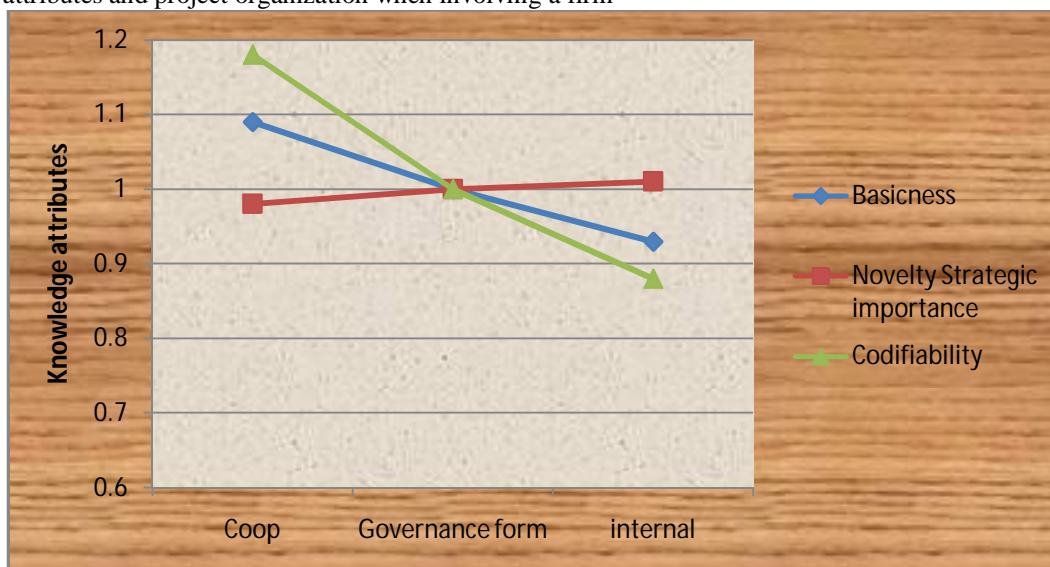
To better pinpoint the role university may play, we contrasted these results with those observed for the firm's propensity to establish linkages with other business firms (see figure 3, which displays the ratio between the average value of knowledge attributes across organizational forms and the sample average of the same attributes for projects involving – or not – other business firms). The first result, somehow related to institutional differences between the two types of organizations, is that generally almost no activity is contracted out to business firms. As a matter of fact, Lacetera (2005) argues that some projects may be contracted out to universities precisely because of the different mission universities and firms have. Outsourcing a project to a university allows a firm to commit not to terminate or alter a scientifically (but may be not commercially) valuable project before completion.

The second matter of divergence is that there is a clear difference between the strategic importance of the projects carried out in cooperation with a firm and those that are not, hinting at a higher concern of opportunistic behavior from

business partners. Along the same lines, in novel projects the firm does not generally establish cooperative agreements with other firms.

The results of the logit analyses aimed at estimating the propensity to cooperate with another firm in an R&D project are presented in table 6. Specification (1) shows that the more basic a project, the more likely it is to cooperate with a firm ( $p < 0.01$ ). Conversely, the parameter estimates of the novelty of knowledge and its strategic importance are negative and highly significant (respectively  $p < 0.05$  and  $p < 0.01$ ). We may infer that projects carried out in partnership with a firm are basic but fairly related to the state of the art. Again, the negative effect of the project's strategic importance may indicate the 'fear' of opportunistic behavior, therefore discouraging cooperation. Results are robust to the introduction of financing program dummies, with the exception of the novelty of the knowledge, which then becomes marginally significant. Results remain also robust when introducing the dummies of the innovation lines.

Knowledge attributes and project organization when involving a firm



Propensity to cooperate with another firm.<sup>a</sup>

	(1)	(2)	(3)
Constant	0.56 (2.19)	8.84† (5.01)	0.58 (3.78)
Project cost	0.04 (0.07)	-0.05 (0.11)	0.00 (0.08)
Basicness	7.14** (2.43)	17.79** (7.22)	8.61** (3.00)
Novelty	-2.45* (1.13)	-2.17† (1.31)	-2.13 (1.48)
Strategic importance	-1.50** (0.62)	-1.72† (1.07)	-2.41** (0.87)
Codifiability	0.42 (0.38)	0.39 (0.57)	0.75† (0.46)
Origin = University		(b)	
Origin = Other Firm		(b)	
Dummies for innovation			
Line included	No	No	Yes
N of observations	52	37	50
X <sup>2</sup>	21.64***	19.05***	27.92***

†  $p < .10$  \* $p < .05$  \*\*  $p < .01$  \*\*\*  $p < .001$

<sup>a</sup> Standard errors in parentheses.

<sup>b</sup> Dummies dropped because they predict success (origin = firm) and failure (origin = univ) perfectly.

**Projects' organization and performance**

The first step in our performance analysis was to build a measure of projects' performance based on the survey items. Our data indicate that performance is a bi-dimensional construct. Several statistical indicators, such as correlation between items, principal component analysis and Cronbach's alpha coefficients, concur to clearly indicate that two dimensions of projects' performance are observed. One dimension picks up project efficiency and short term benefits (e.g. tasks are

accomplished, project is on budget; Cronbach alpha = 0.86), while the other includes learning and long-term benefits (i.e. new applications are discovered, new capabilities are acquired; Cronbach alpha = 0.77). Thus, while efficiency and cost – minimization are surely important objectives, learning and the development t of capabilities constitute another relevant concern.

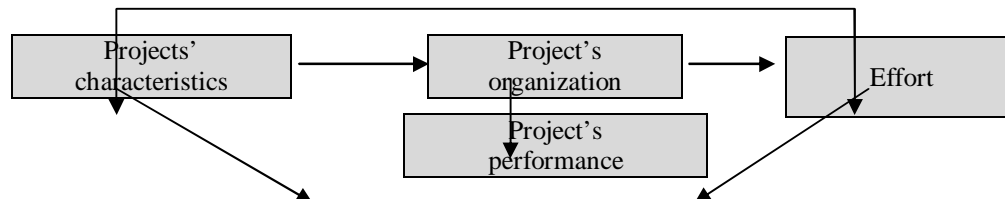
Next, we pose the question: how does the organizational form of the R&D project affect these performance dimensions? Simple tests for difference in means suggest that, despite a general positive effect of university contracting, projects carried out in cooperation with universities generally underperform in terms of efficiency those that are not (see table 7).

Should we conclude that spanning the boundaries of the firm when organizing R&D projects has a negative effect on performance? Why is it that a company well known for its history of successful technological cooperation actually perceives a negative utility of cooperating with universities at the project level? And how is it possible to combine these results at the project level with the bulk of evidence at the firm-level that highlights a positive effect of establishing links with universities? Finally, why not all the projects are contracted out, if that is so beneficial?

Undoubtedly, the general negative effect of cooperation may be due to some organizational disruptions, which are frequent in such agreements (Sobrero & Roberts, 2001). However, the negative correlation between project performance and cooperation may also be the outcome of a more complex mechanism. To understand the effect of organization on performance, we need to gain a deeper understanding of the process through which this may take place. We conjecture that project performance is a function of: (a) the effort the team puts into the project, (b) the intrinsic characteristics of the project (which may make the same level of effort more or less productive), and (c) the project’s organization. Still, the organizational form a project is not decided independently of its characteristics. The optimal organizational form for a project is endogenously chosen on the basis of the project’s specific characteristics (see figure 4). For instance, it may then well be that some projects are outperformed by other because of their specific characteristics, which may make them inherently more difficult to carry out. If these characteristics also increase the propensity to cooperate, we may be driven to the wrong conclusion that cooperation worsens performance. Moreover, we could not expect that any organizational form has an unconditional, unidirectional effect on performance (Shaver, 1998). It is known that when a performance measure is regressed on a strategy choice dummy variable (indicating for instance the organization of the project), the coefficient of the dummy variable will into capture accurately its effect on performance unless (a) firms take decisions randomly or (b) all factors that influence performance can be identified and incorporated in the model. If these conditions do not hold, the coefficient of the dummy variable (e.g. the effect of project’s organization on performance) will be biased.

Though the small number of observations does not allow sophisticated economic techniques, one possibility to control for the endogenous decisions concerning the organization of R&D projects is to regress the project performance measure also on the propensity to adopt a certain organizational form, easily obtainable through a logistic regression (Imbens, 2004). Making this correction, all the results of organizational form of performance disappear (we tried different specifications and results are robust; see table 8, which besides these important covariates, include also some relevant control variables). With one notable exception: contracting with university does show a significant positive effect on learning. This result suggests that organizational decisions are taken to optimize project efficiency, but not learning. Learning effects may be conceptualized as positive externalities for future projects, which can be captured mainly at the firm level. We speculate that project managers, i.e. those who take the decentralized organizational decisions, do not have sufficient incentives to invest in learning.

**Determinants of project’s performance.**



**Differences in projects’ performance.**

		Average Efficiency		Average Learning		cooperation	
with university?	Yes	4.77*	5.32				
	No		5.54	4.79			

Contracting with university?	Yes	5.71*	4.35*
	No	4.72	5.75

\*t-test and Kruskal-Wallis test for difference in mean significant with  $p < 0.05$

**Determine of projects' performance**

	Efficiency	Learning
Contracting with university	0.30 (0.35)	0.98*(0.44)
Coop with university	-0.55 (0.38)	0.42(0.48)
Propensity	Included	Included
Strategic importance	0.75** (0.24)	
Project cost	0.04 (0.04)	
Novelty		0.85* (0.40)
Basicness		1.50 (1.17)
N of observations	39	39
F	5.75***	7.42***

†  $p < .10$  \* $p < .05$  \*\*  $p < .01$  \*\*\*  $p < .001$

**V.DISCUSSION AND CONCLUSIONS**

Faster technological development, shorter product life-cycles, and more intense global competition have transformed the current competitive environment for most firms. In such environment, innovation has become crucial to achieve competitive advantage. Latterly, researchers have emphasized the great potentiality of opening the boundaries of the innovation process. This is the era of “open innovation”, as Chesbrough (2003) labeled it. And in this era, universities are playing an increasingly important role as business firms’ partner, contributing meaningfully to their competitive advantage (Mansfield, 1998; Belderbos et al., 2004). In this paper, building upon the case of ST Microelectronics, we have provided novel evidence on the how and the why of industry science links.

Several limitations of this study warrant attention, though we believe that these could also highlight some points of strength. True enough, the nature and the dimension of our sample can only provide preliminary and exploratory results. And although this study has clearly the potential for application in other settings, results may be hardly generalizable. However, given our research design, we were able to obtain exceptionally fine –grained data, sacrificing quantity for quality. Furthermore, analyzing the case of one single firm automatically controls for a series of other effects, difficult to capture, that may have an influence on innovation strategy and R&D organization and allows focusing on the only dimension left: project features.

Our empirical investigation consisted of two stages: (1) an analysis of the determinants of R&D projects organization and universities’ involvement, and (2) an analysis of the consequences of the different organizational forms on project performance.

In the quest for the drivers of governance decisions, we contended that the attributes of the knowledge involved in the R&D projects should play a fundamental role. And indeed, consistent with prior related literature (e.g., Zander & Kogut, 1995; winter, 1997). We find that knowledge does affect firms’ R&D strategy and organization. Though two distinct dimensions of project performance exist – efficiency and learning – our results suggest that universities are sought mainly for efficiency reasons. On the one hand, we found that in projects devoted primarily to build new knowledge (as opposed to apply it), inherently more costly and complex from a knowledge perspective, the probability of establishing cooperative agreements with universities is much higher. On the other hand, the performance results also suggest that project managers – that is, those who decided about formal linkages in R&D projects – are driven by efficiency reasons when making their organizational choice. Yet, somewhat in contrast with prior literature (e.g., Pisano, 1990; Ulset, 1996) efficiency considerations seem to be driven more by production costs rather than by transaction costs concerns. Our results therefore show the importance of complementing transaction costs considerations with views that emphasize firms’ resources and capabilities. In a dynamic environment, building knowledge may be more important than protecting it. While TCE guards against the hazards that co-developing knowledge involves it has also to be recognized that firms differ in their resources and that cooperation in R&D can provide more productive and complementary resources as well as valuable opportunities for learning.



Our study also highlights some differences between R&D project organization and technology sourcing. Technology sourcing decisions are amongst the most important choices management faces in today's globally competitive environment. Typically, firms may decide whether to develop a specific technology internally, in cooperation, or if to acquire it through licensing or acquisitions. Yet what applies to particular technologies is not necessarily valid for R&D projects. Technology sourcing refers to a given, definite set of knowledge and objectives. R&D projects diverge as for the uncertainty involved, broadness of applicability, risk, and distance from market application (Hauser, 1998). Technology sourcing is about meeting present technological needs; R&D is about building future scenarios (Rosenberg, 1990). And as a matter of fact, while in technology development uncertainty brought about by novelty is generally correlated with external sourcing or development (Steensma & Corley, 2001), this is not the case for R&D projects. The novelty of knowledge has not a significant effect on the propensity to cooperate. Actually, two different interpretations of uncertainty failure is the dominant dimension of uncertainty, while the very results of the project are uncertain in R&D. In the former case, there is uncertainty on the value of a given outcome, which will be partially determined by the environment, in the latter, on what the outcome itself will be. Therefore, in the former case partners are sought to share the commercial risk and possibly establish a standard, while in R&D the cost of monitoring potentially facilitates hierarchical solutions. External solutions are partially exploited through contracting. Delmas (1999) finds also that development through alliances is favored over contracting in the case of strategic technologies. Though our data is not directly comparable, we find rather opposite evidence. We submit two interpretations. First, given their more definite nature, technologies allow for more complete contracts and thus alleviate the risk of opportunistic behavior. And second R&D projects are closer to the heart of firms' future, and thus the value in jeopardy is higher. Hold -up is more of a concern.

We believe that our results about project organization should inform also future econometric studies at the firm level. A better understanding of the drivers of firms' decisions to engage in formal links with universities may improve our ability to account for endogeneity in studies aimed at measuring the performance outcome of industry-science links.

Our study provides interesting insights also from the analysis of projects' performance. Though our empirical results must be interpreted cautiously because of the small size of the sample, we found that when controlling for the endogeneity of project organization decisions, project efficiency is not influenced by the organization, as expected. However, learning is still influenced positively by the presence of university. How can we interpret these results and why do they matter? To begin with, the fact that performance is a multidimensional construct not only points to the well known necessary balance between long term and short term, or exploration and exploitation, but also to how firms should allocate resources and design incentives for project managers to weigh up efficiency and learning. Moreover, the fact that after controlling for the endogeneity of organizational decisions there persists a positive effect of organization on learning could signify that project managers are not optimizing on learning. And if this is the case, this is due to the lack of incentives to do so. Most likely, firms cannot provide high powdered incentive on learning in that learning is not (immediately) observable and contractible. If project managers are purely rewarded on the basis of efficiency, then learning will necessary be overlooked.

What solutions can be adopted to address this issue? First, a balanced set of performance indicator, which varies across project and R&D tiers, can be used, weighting efficiency and formalized measures more heavily in more applied projects and activities. Second, and more importantly from an innovation strategy perspective, a firm can carefully select its portfolio of projects. By committing to the execution of some type of projects, a firm may assure some level of learning – at the firm level. As argued, the selected project characteristics lead to a specific project organization spanning the boundaries of the organization, implying a higher degree of openness and learning.

## VI.CONCLUSION

Moreover, as the results highlight it is not possible to draw unconditional lessons on the impact of an open innovation strategy. The value created by an open innovation strategy is contingent upon the situation. Actually, it may even appear that opening the boundaries of innovation has a negative impact on performance. However, the performance of a given project should be compared to the performance that same project would have had, had cooperation not occurred. Therefore, if projects carried out in cooperation systematically differ from those developed fully internally, then simply comparing 'open' and 'closed' project may lead to erroneous conclusions. Finally, not only has organization a direct effect on performance, but also an indirect effect through the effort. Different organizational forms may have different effects on the incentives researchers have to perform.

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