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The management of industry–university joint research projects: how do partners coordinate and control R&D activities?

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Abstract Benefits derived from industry–university joint research projects (e.g., competitive advantages for firms, opportunities for field experimentation, the funding of academics' activities and knowledge and technology transfer among partners) are strongly affected by the management system exploited to combine partners' resources and tasks. Nevertheless, scholars have not paid great attention to management practices of collaborative research, leaving the best practices undefined. Aiming to fill this literature gap, this paper is a first attempt to open the black box of the management of the implementation stage of research and development (R&D) cooperation. The investigation, based on case studies, focuses on *how* participants of R&D cooperation coordinate and control their activities and *what* drives the selection of integrating mechanisms. The comparison of coordination and control systems implemented in six industry–university joint research projects highlights that planning and mutual adjustment practices are combined in different ways to manage R&D cooperation. Project and relationship characteristics affect the configuration of the management system. Task uncertainty leads to the decentralization of coordination and control practices, equivocality provides incentives for group coordination mode and reduces the need of informal ongoing monitoring and reciprocal interdependence among partners requires the exploitation of up-to-date project plans.

Keywords University–industry link · R&D cooperation · Strategic alliance · Product innovation

JEL Classification O32

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1 Introduction

Research and development (R&D)[1] cooperation allows firms to face the complex and interdisciplinary nature of today's innovation processes (Brockhoff et al. 1991; Hagedoorn 1993; Das and Teng 2000). The literature highlights several positive consequences of inter-organizational arrangements on the innovation capability and economic performance of their participants (Hamel 1991; Sakakibara 1997; Stuart 2000; Lööf and Broström 2008). Those benefits comprise, for instance, the achievement of critical mass for innovation and the access to complementary resources, technology and knowledge transfer, the sharing of the costs and risks of innovation and the penetration of new markets (Tyler and Steensma 1995; Albors 2002; Ryall and Sampson 2003). At the same time, previous studies show that R&D cooperation is characterized by high failure rates (Brouthers et al. 1997) and lower-than-expected performance (Spekman et al. 1998; Madhok and Tallman 1998). Several reasons justify the breakdowns. An agreement may fail due to the selection of unsuitable partners (Beamish and Inkpen 1995), improper governance structure (Sampson 2004) or the under-estimation of day-to-day communication and management issues (Kelly et al. 2002). While the drivers of partners' choice and governance selection have been extensively investigated (Oxley 1997; Mowery et al. 1998; Das and Teng 2000; Daellenbach and Davenport 2004; Santoro and McGill 2005), practices employed in managing partners' activities in collaborative research have not received the attention they deserve. Consequently, they are still a black box that needs to be opened to identify guidelines for the improvement of the performance of R&D cooperation.

The present study sheds some light on the management system of R&D cooperative agreement by examining the coordination and control modes exploited by participants to integrate and supervise their efforts in a joint research project. The focus is on industry–university collaborative researches.[2]

The analysis starts with a literature survey on R&D management and strategic alliances to determine the factors that may affect the characterization of a coordination and control system for R&D cooperation (Sect. 2). Insights from these contiguous literature streams are needed because R&D cooperation literature does not provide sufficient suggestions to drive the investigation of case studies on management system of industry–university cooperation. The literature survey also aims to highlight why the management system of industry–university research projects might differ from that of inter-firm cooperative agreements and consequently aims at evaluating the opportunity to apply the results to other types of R&D cooperation (Sect. 3). Empirical investigation based on a multi-case study approach (Sect. 4) collects detailed information about features of participants, joint research projects and their coordination and control systems (Sect. 5). By comparing cases, it shows that the selection of mechanisms exploited to coordinate and control joint research activities is predominantly affected by task uncertainty, equivocality and the interdependence of partners (Sect. 6).

[1] R&D cooperation is here defined as an agreement where two or more economic actors, driven by common innovating goals and organized by hybrid organization mode, share tangible and intangible resources to develop together a research project.

[2] R&D cooperative agreements may be stipulated among organizations that act at different stages of the same supply chain (vertical cooperation), among competitors (horizontal cooperation) or between academic groups and industrial research laboratories (industry–university cooperation). Benefits and risks, and consequently management challenges, vary across different types of cooperation (Nakamura et al. 2003; Tether 2002). Therefore, to collect data on articulated and comparable cases, it is needed to focus the present analysis on only one type of cooperation.

2 The management system of R&D cooperative agreements: role and configuration

In broad terms, the management of R&D cooperation refers to the handling of the overall R&D cooperative process, that is, the management of the formation, implementation and termination stages. Each alliance phase involves specific management challenges to be accomplished by specialized tools. This study aims to widen the analysis of the challenges of the implementation stage, focusing on integrating mechanisms exploited by partners when they carry out R&D activities together. Previous literature overlooked this toEpsilonc in sEpsilonte of the unquestionable influence of the management system of the implementation stage on the overall effectiveness of an R&D cooperative agreement (Mohr and Spekman 1994; Sicotte and Langley 2000). While scholars have investigated the formation of R&D alliances by examining the criteria that should drive the partners' selection (Mowery et al. 1998; Kelly et al. 2002; Tether 2002) or the different paths followed in the establishment of cooperative agreements (Doz et al. 2000), they have neglected to investigate how to improve the success of implementation and termination phases.

R&D cooperation is a form of strategic alliance (Gates 1993; Yoshino and Rangan 1995; Das and Teng 2000), besides being an open innovation mode (Chesbrough 2003). Therefore, it is expected that its participants must face challenges in both R&D and alliance management. In particular, during the implementation of an R&D agreement, the management system consists of coordination and control practices,[3] which transform the collaborative arrangement into a productive and effective joint execution of the research project and safeguard partners from conflicts. The management system supplements the governance structure in enabling satisfactory cooperation (Sobrero and Schrader 1998). While the governance structure allocates resources and responsibilities, duties and rights to each participant, the management system provides the framework that enables the co-development of technological innovations. In particular, to the contractual obligations and *ex ante* coordination mechanisms (i.e., mutual exchange of rights) provided by the governance structure, the management system adds organizational *ex post* control mechanisms such as performance and behavior monitoring (Dekker 2004) and procedural coordination tools that enable the mutual exchange of information for the combination of agents or functions toward the production of results (Sobrero and Schrader 1998).

Past studies on strategic alliances, R&D management and information processing provide useful suggestions to direct the analysis of R&D cooperation management systems by highlighting factors that affect management challenges. They suggest that in coordinating R&D cooperative agreements, the need for control and information processing may depend primarily on uncertainty, equivocality and the partners' interdependence (Thomas and Trevino 1993; Gulati and Singh 1998; Sicotte and Langley 2000; Park and Ungson 2001; Saberhwal 2003).

Task uncertainty involves the low analyzability of R&D processes and makes it difficult to plan and fully specify research tasks in advance (Argote 1982). As a consequence, it causes an ongoing need to collect and share information to define how to determine what is occurring elsewhere and to deal with disruptions (Galbraith 1974; Sicotte and Langley 2000). Therefore, task uncertainty affects both information processing needs and the exploitability of different coordination mechanisms. In particular, because it reduces the

[3] In the context of R&D cooperation, a coordination system is any process that enables appropriate linkages between tasks (Cray 1984) and to orient individual activities toward the aim of the cooperative agreement (Reger 1999), whereas a control system is a supervision process (Reger 1999) that guarantees the execution of inter-organizational plans (Child 1973).

scope for planning, task uncertainty asks for a large exploitation of mutual adjustment mechanisms.

In strategic alliance equivocality, due to the existence of multiple and conflicting interpretations about goals pursued, problems to be solved and activities needed to accomplish the project purposes (Weick 1979), enhances the risk of misunderstanding among partners (Park and Ungson 2001; Saberhwal 2003) and hampers the effective integration of their resources (Hauptman and Hirji 1999). If participants perceive the risk of equivocal exchanges, then the exploitation of rich personal communication media that provide immediate feedback and utilize a wide range of cues and channels is desirable (Daft and Lengel 1984). These communication media improve information processing and facilitate shared meaning.

Interdependence among partners, ensued by inter-organizational workflows and the extent to which partners are dependent upon one another to perform their individual tasks, affects the needs of data sharing during the collaboration (Chathoth et al. 2005). As the degree of interdependence increases, additive linkage mechanisms are needed to coordinate partners' tasks (Van de Ven et al. 1976). Moreover, taking into account that rules and plans have limited information processing capabilities (Galbraith 1974), coordination by standardization, by plans and programs and by mutual adjustment are suitable to pooled, sequential and reciprocal interdependence, respectively (Daft and Lengel 1986; Grandori 1997).

Aside from task uncertainty, equivocality and partners' interdependence, management challenges can vary also according to the partnership governance, the number of partners, the project team size and partners' geographical proximity. Because of the complementary action of governance and management in minimizing moral hazard risks and enabling activities' integration, inadequate governance structures lead to the need for an increase in the tenacity of operating control practices and in the use of procedural coordination mechanisms (Gulati and Singh 1998; Sobrero and Schrader 1998). Moreover, as the number of partners and people involved in the cooperation increases, their cohesiveness decreases and the information sharing becomes even more complex (Miller 1952; Hare 1962; Grandori and Soda 1995; Sicotte and Langley 2000). As the number of participants increases, the arrangement of collective meetings becomes even more difficult, face-to-face communication gives way to indirect communication, and the adoption of information technologies such as decision support system and email increases (Van de Ven 1975; Sicotte and Langley 2000). The physical proximity of participants involved in a cooperative agreement affects opportunities of informal interactions and face-to-face meetings. In other words, geographical distance narrows the exploitability of some coordination mechanisms and affects knowledge and technology transfer process (Gertler 1995).

3 The peculiarities of the management of industry–university cooperation

Industry–university collaborative research is one of the channels that enable knowledge flow between academia and industry and vice versa (Muir 1997). In the last few years, industry–university cooperation has become increasingly commonplace because it is very effective in generating innovation (Jankowski 1999; Santoro and Betts 2002; Perkmann and Walsch 2007). This type of industry–university interactions facilitates the advancement of knowledge and new technologies and has positive effects on both scientific results and economic performance (Cohen et al. 1998; Santoro and Chakrabarti 2002). For industrial firms, universities represent unique sources of knowledge and technology. For academics, the cooperation with companies represents an opportunity to obtain funds for their own research, for equipment, and for research assistants and leads to opportunities to test practical applications of their theories (Lee 2000).

Industry–university joint research projects differ from inter-firm cooperative agreements in research aims and relational aspects (Tether 2002; Belderbos et al. 2004; Chakrabarti and Santoro 2004). These differences affect the uncertainty and equivocality of these agreements; consequently, their management is differently challenging.

Uncertainty in industry–university joint research projects is higher than in inter-firm cooperation because they are characterized by more ambitious research targets. Industry-university cooperation usually concerns R&D on the technological frontier, on new technological fields and aims at radical breakthrough innovation (Nakamura et al. 2003; Mora-Valentin et al. 2004). As a consequence, participants of these agreements deal with a higher rate of unpredictability of research outcomes and activities to be accomplished, and planning activities are more challenging. These projects ask for a greater resort to mutual adjustment mechanisms.

Equivocality in industry–university research projects is higher than it is in inter-firm cooperation because these arrangements involve interactions between individuals appertaining to systems that are very different in their identity and mission (Siegel et al. 2003). Partners' differences in values and priorities cause a distorted perception about the work of the counterparts (Woolgar et al. 1998). Moreover, contrasting partners' objectives may lead to frequent changes of direction in R&D activities or to termination before completion (Lacetera 2009). Cultural and organizational differences enhance the need for negotiation, mediation and development of a common interpretation of the research aims (Drejer and Jorgensen 2005). Consequently, industry–university cooperation requires a greater use of personal communication media.

The configuration of the management system of industry–university research project is also affected by peculiarities in moral hazard risks. Firms engaged in an industry–university cooperative agreement are usually less exposed to opportunistic behaviors because the risk that the academic partner will become a competitor in the short and medium term is very low. This risk is low because universities lack the complementary assets to directly compete in commercial markets (Berkoviz and Feldman 2007). Firms engaged in cooperation with universities are instead exposed to the risk of its industrial secrets' transfer to another firm through the future cooperation of the academic partner. However, these opportunistic behaviors are widely bound by confidentiality agreements (Lee 2000). Therefore, in industry–university cooperation, the control of counterparts' behavior is accomplished by governance items, whereas the control of results is handled by the management system.

4 Research methodology

4.1 The research design and case selection

The research approach used to study *how* participants in R&D cooperation manage their joint activities and *what* drives the selection of the integrating mechanisms is a multi-case study. This approach is the most effective in dealing with the in-depth understanding of under-investigated complex and multifaceted processes such as the coordination and control system in industry–university research project (Yin 1984, 1993, 2003). It enables an in-depth description of the phenomenon and induces theory building (Eisenhardt 1989). Multi-case design has been preferred to single case "*to create more theory-driven variance* *and divergence in the data that facilitates analytic induction"* (Pauwels and Matthyssens 2004).

The research design involves the comparison of six bilateral industry–university cooperative agreements. The unit of analysis is the coordination and control system of a targeted research project jointly carried out by academic and industrial researchers.

The selection of case studies aimed to identify formal agreements classified as research contracts, involving active participation by both partners and concerning the development of technological innovation in the area of mechanical engineering. To guarantee that participants could provide a detailed description of the agreement management system, only research programs completed no earlier than 1 year before the case study were selected.

To identify candidate cases, an email that explained the design and the purpose of the study was sent to academics at the mechanical engineering department of three universities located in Northern Italy. The professors were subsequently contacted by phone to determine their willingness to participate in the research project and the availability of suitable industry–university joint research projects. Only 20% of contacted professors declared themselves as being engaged in industry–university joint research projects, which satisfy the selection criteria, whereas most of them usually interact with firms for consultancy services and technical tests.

Following Leonard-Barton (1990) and Yan and Gray (1994), each case was selected before the analysis of the previous case was finished. This approach reduces the opportunity that additional cases address some very specific theoretical aspects inadequately addressed by the previous case. However, it allows overcoming the main disadvantage of a sequential sampling process,[4] that is, "*the requirement of extensive resources and time beyond the means of a single student"* (Yin 1984).

As in typical inductive research, data analysis is carried out by first building individual case studies and then comparing cases to construct a conceptual framework. Cross-case analysis exploits techniques suggested by Eisenhardt (1989) and Miles and Huberman (1994) to discover regularities and patterns. An additional technique used is to compare pairs of cases to identify their similarities and differences. Tentative propositions are developed by grouping cooperative agreements according to variables of potential interest (i.e., the ones identified by the literature review).

4.2 Data collection and variables construction

Data collection based on face-to-face semi-structured in-depth interviews with both the participants of the joint research project. Two distinct questionnaires for the industrial partner and the academic partner were used to collect information about characteristics of partners and their relationship, contents and targets of the agreement, organization and management of the cooperative agreement and evaluations about outcomes and cooperation from both points of view. The questionnaires differ only in the section devoted to collecting information about partners' characteristics and in-house R&D practices. Questionnaires prevalently include questions that ask for both quantitative description and qualitative evaluation of the above mentioned features of the joint research project. This means that participants, after assigning a score on a Likert scale, were asked to justify their assessment through description of the attributes or portrayal of illustrative happenings during the joint research project. The demand of both qualitative and quantitative

[4] The sequential selection process suggested by Yin (1984) implies that a new case is selected after the conclusions have been drawn from the previous case.

specifications favors case studies comparability on one side and a better understanding of the meaning people assign to cooperation and its features and decision making processes underlying the joint research project. Participants were interviewed separately to allow the interviewees to express their opinions about the cooperation and the partner without restriction. The two-interview system has been also exploited to enable the identification of disagreement between partners' expectations.

The management system exploited in the implementation phase is outlined through questions about the exploited coordination and control mechanisms. Participants are asked to provide information about the extent of resorting to project plans, integrated information systems, project managers, individual interactions among managers and/or R&D staff, task force and inter-organizational teams to identify the coordination mode. Data on the control activities objects; the frequency of inspections; and the use of managers' meeting, written reports and ongoing informal monitoring practices aimed at checking the project performance and partners' behavior are exploited to frame control practices.

Information about participants, project characteristics and relational features of the partnership are collected to measure uncertainty, equivocality and interdependence.

Following Galbraith (1977), task uncertainty is here proxied by the gap between the amount of information required to perform project tasks and the information that is already possessed. The lack of information is supposed to increase according to the innovativeness of the project goals and to the unfamiliarity of participants with the research subject. The innovativeness is measured by participants' assessments about the positioning of the research results on a radical-incremental innovation scale. The novelty of the research topic is measured asking both participants to evaluate, on a seven-point Likert scale (low–high), the distance between their competence on the application field and their know-how on the specific research topic and that required by the project. Assuming that participants with a great familiarity in the research topic and application field help their partners with less experience, the degree of novelty is defined by the lowest assessment made by participants.

The exposure to equivocality is supposed to depend on both partners' acquaintance and their cultural and technological fit. During the interviews, participants are asked to describe their previous relationship and to assess how much they know the technological competencies, organization and management practices of their counterparts. These assessments are exploited to proxy the mutual acquaintance. The technological fit among partners is estimated due to the comparison of partners' evaluations about the degree of novelty of the research topic and the application field of the cooperative R&D project. A large difference among these assessments indicates a large technological distance. Cultural fit is evaluated asking participants if their different cultural backgrounds cause difficulties and misunderstandings during the project development. The cooperation is supposed to be affected by cultural mismatch even though only one of the participants declares that their cultural differences caused problems during the project's development.

The evaluation of partners' interdependence is based on the division of labor because different workflow patterns entail different degrees of linkage between organizations (Victor and Blackburn 1987). Participants are asked to describe how the research project was split into phases and how the responsibilities concerning the overall research goals and the targets of each project phase were shared. The collected information allow for the discrimination between cooperative agreements that require the simultaneous, tightly-coupled joint activity of participants during the entire project development and those characterized by joint activity only in milestones or in a particular stage of the project.

The interviews also collected information about the number of people involved in the R&D project and their geographical proximity. The informants are asked to assess their project effort in terms of the number of employees involved in the cooperative research to evaluate the overall research team size. Geographical proximity is estimated by travel time spent by partners to have face-to-face meetings, which was calculated using route planner software.

No measures of the governance settings of partnerships and knowledge transfer process have been included in the analysis. These settings do not vary across the examined collaborative researches because the selection process is driven to identify R&D cooperation with the same governance form, and the cooperative agreements are regulated by contracts that were elaborated by exploiting similar research contracts format provided by the universities to professors.

5 Research setting: the industry–university joint research project

5.1 General features

The examined industry–university cooperative arrangements deal with successful small-budget applied research projects. All cooperations result in the introduction of innovations and come up the expectations of both participants.

All projects concern product innovation development but differ in competencies and efforts required to participants because the ambitious nature of research aims as well as the participants' familiarity in the research topic vary across cases (Table 1). Alpha aims at the optimization of ferromagnetic materials for pneumatic actuators, one of the main product line of the firm involved in the agreement. It targets the miniaturization of actuators' components and the signal digitizing. This allows to enhance product performance and give the firm the chance to excel its main Italian competitor, who already manufactures miniaturized actuators but with scanty performance. Beta targets a new functioning conception of asphalt plants in order to satisfy new customers' requirements. The development of new technologies and their application lead to the increase of equipment acceleration and the reduction of the overall dimensions of the plants. The joint research project results in an international patent. The research object of Gamma is the dynamism of turbine machine's components. The target is the development of products that are new for the firm but not for the market. Delta seems the most challenging research project as it involves studies on the technological frontier targeted to a new patentable measurement system applicable to tire in order to enhance the vehicle steadiness. Theta partners enjoy a cooperative research to extend the exploitability of firm's intravolume marking laser systems on transparent materials. Thus, the cooperation provides additional features to an existing products. Epsilon deals with the design of a new labeling system that changes the conception of labeling thanks to the exploitation of new technologies. This leads to a machinery with additional features protected by an international patent.

Alpha and Delta stand out for the unfamiliarity of both participants with the research topic. In Alpha case, the firm is for the first time involved in a research project that targets materials' analysis and characterization whilst the academic staff is not used to deal with the kind of materials that the project focused on and has never looked at applications in engineering industry. In Delta, the project concerns a never investigated research field that try out the creativity of both participants. In all other cases the research topic is in line with R&D activities usually carried out by the industrial partner. This lowers the recoil of the novelty of the research topic on the management challenges even in Beta and Epsilon cases where academic partners are asked to work on a research field not very close to their specialization.

Table 1 General characteristics of the joint research projects

Case	Research object	Type of innovation	Novelty of the research topic[a]	Length (months)	Project team size
Gamma	Dynamics of turbine machine	Incremental	Low	12	19
Theta	Intravolume marking laser system	Incremental	Low	8	10
Alpha	Materials for actuators	Incremental	High	12	24
Beta	Configuration and functioning of asphalt plants	Radical	Low	8	6
Epsilon	Labelling machine	Radical	Low	12	12
Delta	Measurement system for vehicle steadiness	Radical	High	36	30

Type of innovation and novelty of the research topic are measured as described in Sect. 4.2. Note that the innovativeness of the outputs is estimated by both participants. In all cases participants, separately interviewed, provide the same evaluation

[a] The degree of novelty is high when the assessment is upper than 4, low otherwise

Projects differ in terms of their length and the number of people involved in research activities (Table 1). Differences in duration, which ranges from 8 months to 3 years, is a consequence of discrepancy among cases in manifold features such as research innovativeness, the amount of human resources devoted to cooperation, time-to-market requirements, and the firm's strategic priorities. It also depends on the stage reached by the research project when the cooperation begins. Project team's size varies across cases as a result of the varying sizes of the participants' R&D staff and the different allocations of their R&D resources to the joint project.

All agreements concern industry-oriented project and are promoted by the industrial partner that looks for academic cooperation mainly to exploit complementary skills and knowledge (Gamma, Delta, Epsilon and Beta), to access advanced testing equipment (Alpha) or to exploit public funds for innovation (Theta). Knowledge transfer is a further mentioned driver of cooperation but is the main motivation only in Epsilon where the industrial partner aims at "*establishing a long-term relationship with academic staff that enables learning by cooperating or the acquisition of external knowledge and the transfer of technological competencies*" (Table 2). The selection and the involvement of partners, which usually occurs immediately following the definition of the overall research targets and needs, are affected by a firm's previous research cooperative agreements, social ties and business relationships. Personal acquaintance drives the selection in Alpha, Beta and Theta where the firms cut the academic group that employs one of its ex-employee, a university schoolmate of R&D manager or the academic group with whom the R&D manager enjoy research activities during the PhD course, respectively. Recommendations by academic partners of past industry–university joint research projects favor Gamma and Epsilon. The only firm that declares to usually select R&D partners looking for the best-accomplished in the research field is Delta. Promoters' explanations about partners' selection criteria suggest that acquaintance with academic staff is often more important than their technical specifications.[5]

[5] The moderate role of technical specialization's evaluation in partner selection process of industry–university joint research project is justified by difficulties encountered by firms in the gathering of information about know-hows and competencies of academic groups. For instance, Alpha R&D manager complains that universities do not clearly promote their skills. Social ties and personal relationship allow to overcome this problem by enabling the understanding of "who do what".

Table 2 The drivers of cooperation and the features of the partnership

Case	Main drivers of cooperation		Research stage at the beginning of cooperation	Previous relationships among partners	Geographical distance (travel time in minutes)
	Firm	Academic			
Beta	Need of complementary skills	Exploitation the opportunity of funding and of development of competencies	Advanced	The academic group supported the industrial partner in solving a technical contingent problem 6 months before this cooperation	53
Delta	Need of complementary skills	Interest in the topic and will to test theories	Early	Participants experienced cooperation on an equally innovative research project	14
Gamma	Need of complementary skills and exploitation of academic instrumentation	Interest in the topic and opportunity to deepen previous studies	Early	The firm engaged collaborative research with other groups belonging to the same department	39
Alpha	Exploitation of academic instrumentation and need of complementary skills	Exploitation of funding's opportunity and interest in the topic	Early	A member of the academic group worked in the R&D office of the industrial partner till 2 years before the beginning of the examined agreement	13
Theta	Exploitation of public funds	Interest in the topic and will to test theories	Early	The R&D manager of Theta firm obtained a PhD degree at the academic partner before joining the company. Moreover, the responsible of Theta academic group provided firm with technical advices 4 years before the engagement in the analysed cooperative agreement	48
Epsilon	Technology transfer and need of complementary skills	Interest in the topic, relevant for academic community	Early	The firm engaged collaborative research with other groups belonging to the same department	88

Different motivations drive the participation of academicians to these project. Most of them state they are interested in the research topic. However, nobody was engaged in investigations about the research topic at the moment they were asked to enjoy the joint research project. In all cases the academicians interpret industry–university joint research projects as a funding opportunity that cannot be missed because of shortage of money caused by the fall of government funding to universities. Yet, funding opportunity is a main driver of cooperation only for Beta and Alpha.

Moreover, these industry-university joint research projects are often preceded by contract studies or less challenging cooperation, which enables the development of mutual trust on behavior and technical competencies. The narrow social networks of firms and the need to reduce travel time and costs to arrange meetings lead to cooperative agreements characterized by a high geographical proximity of the partners.

Firms engaged are manufacturers of mechanical machinery and equipment, producers of metal products and producers of automotive rubber components. Firm sizes range from 85 employees in companies involved in Theta to 3,723 in those involved in Delta (Table 3). All firms, with the exception of the companies involved in Theta and Beta, belong to a multinational group. Nevertheless, with regards to R&D activities, they are comparable to independent firms because they declare to plan and carry out research activities autonomously from other affiliates. Firms differ in human resources devoted to R&D activities and efforts in planning R&D activities but show a similar attitude toward the exploitation of open innovation strategies. In particular, they are accustomed to entering formal and informal agreements with customers and suppliers to introduce technological innovation. Moreover, all firms, with the only exception of Theta, have already experienced at least one formal cooperation with an academic research group. This outstanding cooperative attitude is shared by the academic research groups involved in the examined cases. The academic partners stand out for their links to industry (Table 4). In particular, they enjoy several research activities in cooperation with industrial laboratories and researchers and are contractors of industrial researches. The attitude toward open innovation strategies of industrial partners and the usual connections with firms by the academic participants enable them develop practices to protect cooperation from differences in cultural backgrounds. As a consequence, the examined arrangements are not negatively affected by industry–university cultural differences. However, this is not the result of the lack of partners' cultural differences but rather it's the consequence of awareness and acceptance of them by both participants. This allows to mediate different research approaches, different interests and timing.

Although natural divergences between academicians and industrial interests and differences in drivers of the cooperation remarked by interviewees, all participants agree on the usefulness of cooperation in research activities and on the benefits that they reach thanks to co-working. They appear satisfied and are well predisposed for further cooperative agreements with the same partners. All participants rise their internal technological competencies by cooperating. However, only in Delta and Epsilon the impact on know how is equal in the two partners. In Alpha and Beta industrial partners report a greater effect than academic partners. In the other cases, it happens the opposite. Yet, both sides experience the benefits of the exploitation of synergies among partners' skills and know-how.

5.2 Task uncertainty, equivocality and partners' interdependence

Divergences in research goals' innovativeness and the familiarity of participants with the topic make cooperative agreements have different degrees of susceptibility to task

Table 3 Characteristics of the industrial partner

Case	Structural characteristics		R&D resources and organization		R&D practices		
	Size (employees)	Industry (products)	Full-time R&D manager	% R&D employees (full-time equivalent)	Formulation of R&D strategy	Detail of in-house R&D project plans[a]	Engagement in R&D cooperation
Theta	85	Laser system	No	4.12	No	2.4	It is accustomed to informal vertical cooperation, but it has never been involved in joint industry-university research projects
Epsilon	118	Packaging technologies	Yes	4.24	Yes	7.0	It cooperates with suppliers daily, never cooperates with competitors and is accustomed to cooperating with universities
Beta	160	Asphalt plants	No	3.44	Yes	3.2	It cooperates only with universities
Alpha	350	Pneumatic components	Yes	13.43	Yes	3.8	It often exploits vertical cooperation and cooperation with universities
Gamma	870	Power generation plants	No	2.87	No	4.2	It cooperates mainly with universities
Delta	3,723	Tire	Yes	10.74	Yes	6.2	It is accustomed to exploiting every type of cooperation

[a] Average of the assessments about the detail of goals' definition, phases and tasks description, allocation of resources in in-house R&D projects. Each assessment is stated on a 7-point Likert scale

Table 4 Characteristics of the academic partner

Case	Team size	Specialization	Frequency of interactions with firms
Gamma	28	Applied mechanics	High (often involved in contract research and innovation co-development with manufacturing firms)
Delta	28	Applied mechanics	High (performs testing services for companies and often engaged in contract and collaborative research with them)
Epsilon	8	Applied mechanics	High (often involved in contract research and innovation co-development with manufacturing firms)
Theta	10	Optoelectronic	High (often involved in contract research and innovation co-development with manufacturing firms)
Beta	3	Mechanical design	Very high (most of research activities carried out in cooperation with companies)
Alpha	18	Applied chemistry	Very high (most of research activities carried out in cooperation with companies)

Table 5 Task uncertainty

	Low novelty of research topic	High novelty of research topic
Radical innovation	Beta Epsilon	Delta
Incremental innovation	Gamma Theta	Alpha

uncertainty (Table 5). In the case of Delta, the development of radical innovation in an almost new research field makes it difficult for participants to foresee how to reach alliance goals. As a matter of fact, Delta is the only case where the firm highlight a great dynamism of project plans and the unachievement of planned goals because "*what was supposed at the beginning becomes not plausible during the project development*". In contrast, low task uncertainty is faced by both Gamma and Theta participants because they engaged in R&D activities aimed at incremental technological breakthroughs in a familiar research field. The other cases of collaborative research are characterized by intermediate task uncertainty.

Equivocality varies across partnerships because of the misalignment of participants' technological backgrounds and dissimilarities in their mutual acquaintance at the beginning of the cooperation, that curiously is not always correlated to the nature of previous relationship between partners (Tables 6, 7). For instance, although participants of Epsilon do not experience past direct cooperation they declare to know each other very well. This is the result of the mediation carried out by colleagues of the academic staff who was firm's partner in previous industry–university joint research project.

Information about divergences between partners' technological competencies in the research field make suppose that technical misinterpretations are more likely in Beta and Epsilon whereas Gamma, Beta and Alpha are expected to me more exposed to misunderstandings due to industrial partners' low cognizance of counterparts' practices. Actually nobody complains difficulties in the management of the research project and quarrels because of low mutual acquaintance.

Regarding partners' interdependence, the examined cases can be arranged into two groups. Delta, Epsilon and Alpha, where partners collaborate in achieving goals in the

Table 6 Factors affecting equivocality

Case	Mutual acquaintance[a]		Technological distance[b]
	Acquaintance of industrial partner by the academic one	Acquaintance of academic partner by the industrial one	
Alpha	++	−	Low
Gamma	++	−	Low
Beta	++	−	High
Delta	++	+	Low
Theta	++	++	Low
Epsilon	++	++	High

[a] The participants are asked to evaluate how much they know the technical competencies, skills, the organization and managerial practices of their project's counterpart at the beginning of the project. The average of the assessments, which are expressed on a 7-point Likert scale, is classified in 4 classes: ++ if the average is above 5.5; + if it is between 4 and 5.5; − if it is between 2.5 and 4; and −− if it is below 2.5

[b] Technological distance is high if the assessment about knowledge asymmetry between partners in the research field is above 3, low otherwise

Table 7 Equivocality

	Low technological distance	High technological distance
Low mutual acquaintance	Gamma Alpha	Beta
High mutual acquaintance	Theta Delta	Epsilon

Table 8 Task uncertainty, equivocality and interdependence

	Task uncertainty	Equivocality	Interdependence
Theta	Low	Low	Sequential
Gamma	Low	Medium	Sequential
Alpha	Medium	Medium	Reciprocal
Epsilon	Medium	Medium	Reciprocal
Beta	Medium	High	Sequential
Delta	High	Low	Reciprocal

majority of the research phases, are affected by reciprocal interdependence. In Gamma, Theta and Beta each participant is assigned specific activities whose outcomes are combined in the milestone points. In these cases, the division of labor among partners leads to sequential interdependence (Table 8).

5.3 Coordination and control systems

The management systems of the investigated cooperative researches are based on different sets of coordination and control mechanisms (Table 9). The heterogeneity in coordination and control systems demonstrates that various management practices can drive the integration of participants' activities. The simplest one involves the use only of formal and informal contact among partners' managers (i.e., Gamma and Theta), whereas the most

Table 9 The management systems

Case	Standardization of outputs	Plans and schedules		Mutual adjustments						
	Detail of research goals' definition	Detail of initial plans[a]	Plan review	Meetings among managers	Informal contact among managers	Task force	Inter-organizational team	Informal contact among R&D staff	Technical report	Ongoing informal monitoring
Gamma	7	7		+	++				+	++
Theta	6	6.7		+[b]	++				++	
Beta	7	6.3		+[b]	++	+			+	++
Alpha	7	5	✔		++			+	+	++
Delta	7	7	✔		+		++		++	
Epsilon	7	6.7	✔	+	++	+	+	++	+	

Empty cell = the mechanism is not exploited; + = minor exploited mechanism; ++ = main exploited mechanism

[a] The detail of initial plan is the average of participants' assessments about the detail of goals and tasks descriptions, human and financial resources allocation and foresight of benefits and risks in the initial project plan

[b] Meeting among managers in Theta and Beta are exploited only to control partners' activities instead of coordinate them

complicated exploits project plans, formal and informal interaction among managers and partners' R&D staffs, task force and inter-organizational teams (i.e., Epsilon).[6]

Control practices are usually interested in the evaluation of intermediate goals. The monitoring of the counterpart's behavior is not performed because the participants are not worried about opportunistic attitudes. The contractual clauses about the intellectual property rights and the credit transfers are considered sufficient to appease the potential cares of firms about the low commitment of the academic partner and the possibility that their partner transfer their know-how to their competitors.[7] Moreover, mutual trust among partners, developed thanks to previous cooperation or due to personal relationships between partners' members, leads to overlook control practices.

The investigation of coordination and control practices shows that project managers and integrated information systems that are not included in Table 9 are not used in any joint research project. On the contrary, in all cases, partners consider it appropriate to spend time to describe project research goals in detail. Moreover, they develop project plans, where they usually define, allocate and schedule project tasks. Industrial partners devote more effort to the definition of plans in these collaborative R&D projects compared to the effort devoted in in-house R&D. However, despite the great effort devoted to planning activities, the initial plans do not always provide exhaustive explanations of the activities needed to reach the planned goals or a detailed description of project opportunities and challenges. Moreover, although these initial plans quickly become obsolete, only in Delta, Epsilon and Alpha do the participants update them.

Mutual adjustments mechanisms are the main tool exploited to manage cooperative research.

Informal interactions among managers by telephone or email are the most used coordination mechanisms in all cases, with the exception of Delta, where partners prefer to coordinate research activities through inter-organizational teams. Managers' interactions are generally frequent in all phases of the projects and aim to update the intermediate research goals and to support the timely integration of partners' activities.

Formal meetings among managers generally target control purposes rather than coordination and, in some cases, serve to solve administrative problems. Planned meetings among managers usually occur at the end of each project stage. However, in some cases, formal meetings are also organized during the development of each stage whenever difficulties arise. Delta and Alpha are the only cases that do not resort to this coordination and control mechanism.

The adoption of inter-organizational teams where members of the academic partner stay and work directly with the industrial partner (or vice versa) for the duration of the entire project or for that of a project's phase is rare. Temporary group meetings of partners' R&D staff (task forces) are usually preferred. Finally, the importance given to informal interactions among partners' staff varies significantly across cases. All of the different types of interactions among partners' staff have several aims, such as the updating of research goals and tasks, the redefinition of the division of labor, and the integration of the outcomes of partners' activities.

[6] Both participants, but at different moments, are asked to describe coordination and control mechanisms employed to manage the joint research project. In all cases, descriptions provided by partners correspond.

[7] Contracts include clauses that oblige the academic partner not to cooperate with competitors during the development of the joint research project and clauses that provide deadlines for the completion of the work as well as the achievement of the planned outputs before the liquidation of grants by the industrial partner. These clauses prevent opportunities for both of the partners to be victim of moral hazard risks.

Written reports are frequently used in industry-university joint research projects with a twofold function: they are useful for formally controlling the outputs of the research activities carried out, and, at the same time, they facilitate the transfer of intermediate findings if the interdependence among partners is sequential. In Gamma and Theta, reports are compiled at the end of each stage of the project. In the other cases, partners also exchange reports during phases.

In half of the cases, the advancing of project tasks is also controlled by informal monitoring. These control practices are applied in the phases that involve practical R&D activities such as testing or when task uncertainty is low and both intermediate and overall goals are clearly identified.

6 Findings

6.1 Integrating mechanisms in industry–university research projects

To coordinate and control their activities, participants in industry–university research projects combine planning and mutual adjustment mechanisms in different ways against a similar exploitation of output standardization. Whatever the degree of task uncertainty, equivocality or interdependence, participants engage in a detailed description of awaited outcomes during the negotiation phase, which means that the management system of the implementation stage of industry–university research project is based on the scrupulous specification and the sharing of the overall research goals. The recognition of project targets since the very beginning helps participants to focus their efforts on R&D activities that accomplish the project goals that the counterpart is waiting for. This reassures all industrial participants, promoters of the analyzed joint research project, who fear "*the misalignment between their interests and the ones of the Academy*" (Delta R&D manager). Output standardization provides an upper reference frame that narrows coordination challenges during the project development. Moreover, a detailed description of research goals favors the comparison between reached and awaited results during the project development. This description helps to keep the collaborative research under control. Therefore,

Proposition 1 *In collaborative research, the effective fit of partners' efforts depends on the standardization of outputs.*

The integration of partners' individual deeds in industry-university research agreements also depends on planning activities carried out to allocate goals and responsibilities and to define and schedule tasks (see the high rates of the detail of initial plans in Table 9 and compared them with those of in-house R&D projects in Table 3). In the examined cases, before engaging in the project's implementation stage, participants develop well-detailed project plans even in difficult cases to predict the tasks needed to reach the research goals (i.e., Delta). The tendency toward detailed planning is lessened when a medium level of technological uncertainty is combined with a low mutual acquaintance rate (i.e., Alpha and Beta). Despite participants' efforts, the initial project plans swiftly become obsolete and, consequently, unhelpful for guiding the project development in all the examined cases. However, this plans are updated only in those affected by reciprocal interdependence, which means that only when partners' activities are mutually interdependent are plans actually needed as a coordination tool during the implementation stage; however, the initial planning is recommended in all cases because it involves partners in a socialization process that facilitates sense making by focusing attention and forcing articulation, deliberation and reflection (Vlaar et al. 2006). Initial planning reduces misunderstanding and tension during the implementation stage. Therefore,

Proposition 2 *Planning activities at the beginning of the cooperation is desirable whatever the opportunities to workout detailed and exploitable project plans because they enable the alignment of partners' efforts. Up-to-date project plans are needed to coordinate partners' activities in the implementation stage only when partners are bounded by reciprocal interdependence.*

Whatever the role assigned to output standardization and planning activities, participants declare that formal and informal interactions among project members is fundamental. Moreover, regardless, the investigation of coordination and control systems exploited in the examined agreements highlights that project plans are not sufficient to manage R&D cooperation and that mutual adjustment mechanisms are generally more important than planning activities. This result is just typical because R&D cooperation is usually affected by the lack of incomplete information, which makes it difficult to predict the future states of many factors associated with cooperative agreements and tasks. Accordingly, it is difficult to properly specify in advance the way to reach the desired results. This difficulty enhances the information processing needs during the implementation phase and, consequently, enhances the use of mutual adjustment mechanisms that counterbalance the fact that neither party knows ahead of time what it aims to do. Therefore,

Proposition 3 *In industry–university joint research projects, coordination by plans has a secondary role compared with coordination based on mutual adjustment.*

6.2 Mutual adjustment practices

To coordinate their activities, the participants in industry-university cooperative research mainly resort to horizontal links among partners that favor information exchange during the development of the R&D project. Persuasion, negotiation and exchange of information are preferred to formal central authority. In particular, they are preferred to the designation of a project manager. The participants declare that they do not feel the need to name a project manager because "*these R&D cooperative agreements involve only two organisations. The coordination of partners' activities can be reached by more simple mechanisms*" (the R&D manager of firms involved in ALPHA project). However, the absence of a project manager can also be explained by the fact that, generally, no organization is likely to give a manager of another organization the authority over its own system (Wren 1967). As a consequence, they select a project manager only when it is absolutely necessary, such as when the challenges in coordination arise due to the interdependence among a wide set of participants.

In the absence of a project manager, the effective development of these joint research projects depends on prompt information sharing among participants, which can be guaranteed by personal liaison devices and/or integrated information systems. In the examined cooperative agreement, partners prefer the first option. They do not use an integrated information system. The strict focus of the projects and the dyadic nature of the cooperative agreements do not require specialized ICT investments. Moreover, the transitional nature of the agreement deters participants from carrying out relation-specific investments such as the implementation of an inter-organizational information system.

Meetings and informal interactions among managers are the main mechanisms exploited to integrate partners' activities. Therefore, to manage bilateral industry–university cooperative research, it is essential to identify a person in charge of the project in each organization involved. These people hold liaison roles that act as a bridge between organizations. The R&D manager of the firm and the full professor of the academic group generally cover these positions. Therefore, the main integrators are individuals who have hierarchical power inside the organizations.

Proposition 4 *The management of dyadic R&D cooperative agreements does not require a unified central coordinating body such as project managers, but rather, it needs liaison positions held by people with formal authority and a hub role within their organizations.*

The role played by R&D staff in coordination and control practices varies extensively across joint research projects according to task uncertainty. Where participants deal with the development of incremental technological changes in almost familiar research fields, coordination and control activities do not involve R&D staff (Gamma and Theta). Conversely, where participants are engaged in a research project at the technological frontier and consequently deal with high task uncertainty, R&D staff is greatly entrusted with coordination duties (Delta). In collaborative researches characterized by medium task uncertainty, R&D staffs are assigned coordination and control practices but have a minor role compared to managers. Giving space to unexpected events during the project development, task uncertainty asks for the ability to react to occurrences in a timely manner. Therefore, the cooperative studies with high task uncertainty imply that decisions must be made rapidly. Consequently, a less centralized decision making process is needed because decentralized communication patterns can deal with work-related uncertainty more effectively than hierarchical. Therefore,

Proposition 5 *The increase in task uncertainty in cooperative research leads to a greater decentralization of coordination and control practices.*

Aside from task uncertainty, a balanced role of R&D staff and R&D managers is also stimulated by participants' technology transfer aims. In the Epsilon case, where participants face medium task uncertainty, they need to greatly involve R&D staff in coordination and control practices to make knowledge transfer more effective.

Proposition 6 *The decentralization of management practices depends also on participants' aims in terms of knowledge transfer.*

The configuration of the management system is also affected by the factors that enhance equivocality. If the partnership is characterized by low mutual acquaintance, as with the Gamma, Beta and Alpha cases, then ongoing informal monitoring practices are exploited to coordinate and control the project's evolution. This suggests that low mutual acquaintance discourages the definition of well-structured and complex coordination and control devices. Technological distance among partners instead demands group coordination, in particular the exploitation of task forces (Beta and Epsilon). In agreements affected by high technological distance, group meetings aim to attenuate differences in a problem's conception and reduce the equivocality of communication. In cooperative research affected by expertise gaps, the coordination at the boundary requires the reconciliation and transformation of knowledge. The involvement of collective interpersonal contacts by the most of the participants enables the overall mutual understanding of technological questions involved in joint R&D projects. This involvement increases the amount of shared knowledge, enabling an effective collaborative learning and working. Therefore,

Proposition 7 *Equivocality due to technological distance is mediated by group coordination mode, whereas equivocality due to low mutual acquaintance discourages complex coordination.*

The investigation does not point out any relationship among participant characteristics and coordination and control systems in industry-university cooperative researches. In particular, the internal R&D management practices of the participants do not reflect themselves in the management system of the cooperative agreement.

Contrary to expectations, management systems do not depend on partners' geographical distance and project team size. The irrelevance of physical distance can be explained by taking into account that even in the cooperative agreement characterized by the greatest distance between partners' bases, face-to-face meetings among participants do not require more than one and a half hours. Consequently, it is possible to arrange journeys there and back during the day. Therefore, the costs of face-to-face meetings do not vary dramatically across cases and, in particular, are economically sustainable in all agreements.

7 Management implications and conclusion

After analyzing the management system of the examined cooperative researches, the results reveal that coordination and control activities in industry–university cooperation are arranged in different ways according to task uncertainty, equivocality and partners' interdependence, which characterize the joint R&D projects and partnerships. These features affect the role played by planning and mutual adjustment mechanisms, the exploitation of group coordination modes and the centralization of management systems. In particular, task uncertainty does not limit, as expected, partners' efforts in the definition of detailed project plans. However, it affects the decentralization of coordination and control practices. A higher degree of task uncertainty indicates a greater involvement of R&D staff because decentralization enables a prompt reaction to unexpected events. Equivocality caused by differences in partners' technological backgrounds leads to the exploitation of group coordination mode, whereas equivocality due to low mutual acquaintance has a negative effect on the formalization of complex coordination and control practices. Partners' interdependence affects planning practices. The updating of project plans as the project develops is required only if partners are interdependent. Apart from uncertainty, equivocality and interdependence, the analysis of drivers of coordination and control also involves the investigation of the impact of other projects and partnership characteristics. However, there is no evidence of relationships between these features and the management system.

The analysis leads to further suggestions for managers who have to deal with cooperative research between industry and academia. With regards to the coordination systems, the analysis highlights that, regardless of the features of the project and partnerships, initially partners should devote themselves to planning activities more than they do for internal R&D process. This safeguards them from misunderstandings during the project evolution due to the misalignment of partners' objectives and the low commitment of partners. Planning efforts aim to create a common perspective regarding the research project. They are particularly needed in industry-university agreements because these agreements are usually affected by a high difference in partners' cultural backgrounds.

On the contrary, the investigation points out that the adoption of teamwork and collocation is restricted to particular circumstances. Only few motivations justify the high cost of teamwork and collocation. One is the need of ongoing information sharing due to task uncertainty combined with reciprocal interdependence. The other is the willingness to exploit cooperation as a learning tool. If the industrial partner is interested in exploiting R&D cooperative agreements to increase its internal know-how through knowledge transfer, the coordination system should be shaped to guarantee high integration and frequent personal interaction.

With regards to control practices, the study points out that its main function is to verify that the milestones of the R&D project are reached. To do so, it is sufficient to clearly define project goals and to exploit them as a reference. Opportunistic behaviors in industry-university joint research projects are governed by the contractual clauses regarding the assignment of intellectual property rights and grant transfers. Moreover, these agreements are set up only if partners deeply trust each other. Consequently, the implementation phase is not affected by moral hazard risks, which usually characterize alliance management. For these reasons, the control system used by agreements in cooperative R&D are closer to those applied in internal R&D projects than they are to those of strategic alliances. Written reports and periodical meetings are effective control means.

In conclusion, this study sheds some light on the management of the implementation stage of R&D cooperation by identifying the features that affect the configuration of coordination and control systems. However, the generalization of its findings is limited by the fact that it focuses only on dyadic industry-university research projects. The involvement of only two organizations in the cooperative research might reduce the need for sophisticated coordination and control mechanisms. Cooperation with academic groups usually involves greater problems in mutual understanding, on the one hand, and lower exposure to moral hazard risks on the other in relation to cooperation among firms. These peculiarities could result in a greater tendency to use personal communication media and exert lower effort in control practices relative to cases of inter-firm cooperation.

Another limit of this study is the under-investigation of unsuccessful joint research projects. The study does not examine unsteady agreements or cases where partners have not reached the planned goals.[8] However, the investigation of unsuccessful cooperation might provide further interesting insights about the pitfalls of coordination and control systems.

For all the mentioned reasons, a general theory of management system of R&D cooperation demands future studies that investigate different types of cooperative agreements and compare findings.

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[8] This may be a consequence of the voluntary-based selection process of case studies. The interviewed professors prefer to propose only cases where the relationship with the industrial partner remains strong after the conclusion of the R&D cooperation.

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