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Forms and Determinants of R&D Collaborations: New Evidence on French Data

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Abstract:
The aim of this paper is to explore the heterogeneity in R&D collaborations and of their determinants and motives. Using a recent French survey on research and innovation relations, we first show the heterogeneity of such relations thanks to a typology of their characteristics: their nature (common research, sub-contracting, multi-partnership, management of a common structure), organizational arrangement (contract, specific investments), duration and type of research (market-oriented vs. research-oriented). Five categories of collaborations are obtained from different combinations of these relational characteristics. Using a multinomial logit estimation (and testing for the IIA assumption), we then try to explain how this diversity of partnerships is related to a broad set of explanatory variables (economic rationale for the cooperation, knowledge spillovers, appropriability conditions and partners' individual characteristics). Thanks to this original approach, we have obtained new results on R&D cooperation motives.

Keywords: R&D collaboration; heterogeneity; spillovers; organizational arrangements
Jel codes: L14; L20; O32

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1. Introduction

Innovation is considered as a source of increased productivity and economic growth. Moreover, it is more and more frequently the fruit of collaborative work because innovation generally requires the combination of various sources of knowledge. As a consequence, the number of R&D cooperations between firms and between firms and public institutions has increased sharply in the last few years (Hagedoorn, 2002; Mansfield et Lee, 1996; Mowery, 1998; OCDE, 2000); this increase has also been reinforced by the financial support the State has provided so as to promote knowledge sharing and creation.

Thus, R&D collaborations are considered as strategic relations for firms. Three main strands of theoretical literature examine firms' incentives to form research partnerships (Hagedoorn et al., 2000). In the strategic management theory, which concentrates on the internal organization of firms' activities, the rationale for R&D cooperation is linked to the exploitation of complementary competencies or knowledge (e.g. Teece, 1986; Kogut and Zander, 1992). From a transaction cost perspective, cooperation is seen as a hybrid form of organization which in certain circumstances can be a preferable alternative to the market or the hierarchy. Finally, the Industrial organization theory, focusing on the role of knowledge spillovers on R&D efforts, examines the incentives for firms to conduct R&D cooperative projects with competitors and the effects on social welfare of this type of R&D cooperation (e.g. D'Aspremont and Jacquemin, 1988; Kamien et al., 1992). Hagedoorn et al. (2000), using a synthethis of these theories, provide a description of the potential benefits of R&D collaboration. Cooperation enables firms to internalize knowledge spillovers, facilitates knowledge transfers between them (in particular between firms and universities), helps them gain access to complementary knowledge and technologies, generates scale economies of research, enables firms to speed the commercialization of new products or technologies, to avoid duplicative R&D efforts, to share costs and uncertainty, to gain access to foreign or new markets.

Thus, much literature has been written about the motives for and potential benefits of cooperation and about the obstacles to cooperative relations as well as the factors of their success. But, although cooperation enables firms to meet various needs and reach certain goals, it has been largely ignored in literature and the heterogeneity of the types of cooperations has been overlooked. As a consequence, our understanding of the determinants and effects of R&D cooperation agreement remains limited. Some scholars have emphasized the need for a more sophisticated and multifaceted approach to cooperation (see for instance Osborn and Hagedoorn, 1997). Thus, some authors (Kaiser, 2002; Cassiman and Veugelers, 2002; Fritsch and Lucas, 2001; Leiponen, 2001; Tether, 2002; Belderdos et al., 2004; Lopez, 2006) have started to examine the nature of the partners in order to deepen the study of the motives and determinants of R&D cooperation. They show that the determinants of and motives for cooperation vary according to the type of partners (competitor, customer or supplier, academic actors). In particular, the R&D intensity is a significant explanatory

variable of cooperation with customers, suppliers and academic partners but it does not explain cooperation with competitors (Belderdos et al., 2004). Moreover, the risk constraint only has an impact on cooperation with competitors or suppliers (Belderdos et al., 2004). However, these studies are based on the hypothesis that one type of partner is associated to one type of cooperation. In other words, it is assumed that a firm always follows the same strategy with a given partner, for instance when it collaborates with a public laboratory. The results of several studies show that this hypothesis is not satisfactory (see for instance, Carayol, 2003; Levy et al., 2006, in the case of public-private research partnerships).

In this paper, we go further in this direction, and explore the heterogeneity of the forms of R&D collaboration. Our aim is to examine the various ways in which (French) firms collaborate and to analyse the strategies that lead to those different types of collaboration. We expect a strong correlation between the decision of a firm to engage in a particular type of R&D collaboration and the nature of its expected benefits. In order to show this correlation, we first propose a typology of the forms of collaboration, based on a large sample of R&D collaboration agreements. Then, using a multinomial logit, we test the influence of a broad set of factors (size of the firm, belonging to a group, R&D intensity of the firm, of its partner, type of motives, incoming spillovers, appropriability conditions …) on the chosen form of collaboration. Our data come from the survey of inter-firm relations (ERIE) conducted in 2003 by the French institutes of statistics (Sessi, Scees, DPE, Insee). The aim of this survey was to provide an overview of interfirm relations. More precisely, the survey studies the firms engaged in cooperative relationships. Our sample comprises firms that have declared having at least one R&D/ innovation cooperative relationship with another organization (1743 firms); these firms are engaged in 3297 relationships, out of which 3072 can be exploited in the framework of our econometric analyses.

The article is organized as follows. In the following section, we briefly present our data. In Section 3, we present and discuss the typology we obtained. In Section 4, we propose a short overview of the theoretical and empirical literature related to the determinants and motives of R&D collaboration. We also present our empirical approach. Our results are discussed in Section 5. The last section concludes.

2. The data

The data used for our research come from a French survey of inter-business relationships (ERIE survey), conducted in 2003 by the French institutes of statistics (Sessi, Scees, DPE, Insee) and coordinated at European level. It aimed to provide an overview of the relations between firms (and other actors) involving a minimum level of cooperation[1]. The survey concentrated on five main aspects of firms' activities: production, procurement, marketing,

[1] This means that usual relations between client and supplier are not covered here (nor purely financial relations).

R&D and innovation, ancillary services (transport, advertising…). For each of these functions, firms were asked to describe no more than three of their strategic relationships. When they were involved in several cooperative relationships with other organizations, they were asked to choose the most three strategic relationships. Two types of questions were asked: questions concerning the partner (nature, location, selection criteria …) and questions concerning the relationship itself (duration, nature of R&D, economic rationale for the relationship, outputs ...). 7611 firms were interviewed for each relationship and for each function. The sample, representative in size and sector, comprises 932 firms from the food sector (Scees), 4175 from the industrial sector (Sessi), 1845 firms from the service sector (Insee) and 659 are R&D firms (DEP).

Out of all the firms in the sample, we have selected those declaring having at least one R&D cooperation relationship. Table 1 reports some sample statistics. It turns out that 1775 firms in the sample have at least one R&D cooperation relationship with another organization (23.32%). Becker and Dietz (2004) find that about 37% of German firms collaborate with other organizations to jointly develop new products. Tether (2002) finds that 45% of English innovating firms cooperate with other organizations. As half of the firms of his sample innovate, we can consider that our figure is similar to his. 18.9% of innovative Spanish firms cooperate (Lopez, 2006). It seems then that Spanish cooperate less than other firms.

The firms of our sample that cooperate with other organizations develop on average 8.94 cooperative relationships but the standard error is large (34.8) and the median is only of 2 relationships. Among firms in the sample that cooperate with others, almost half only have one cooperative relationship (47.72%), 9% of them declare five or more relationships.

Table 1. Number of relationships initiated for the purpose of research and innovation

Number of relationships	%
1	47.72
2	14.93
3	16.28
4	12.23
5 (or more)	8.85

Source : Erie Survey (authors' calculation)

With this sample of cooperative firms, we are confronted with the fact that a firm can describe one, two or three partnerships: how can we deal with this problem especially since there is *a priori* no preference order in the answers between those relations? In order to solve this problem, we build a new database on relations (and not on firms). The initial database has as many observations as firms interviewed. It is presented in Table 2. For instance, firm I only describes one relationship, while firm K describes two relationships (C and D).

Table 2. Presentation of the firm's sample

Firms	Relation 1	Relation 2	Relation 3
I	A		
J	B		
K	C	D	
L	E	F	G

We transform Table 2 into Table 3 in such a manner that the new database has as many observations as there are strategic relationships described by firms. Every observation contains all the information for each relationship and for the partner, as well as the characteristics of the firm that has described this relationship. The sample then contains 3297 relationships.

Table 3. Presentation of the final sample of relationships

Relation	Type	Output	Economic rationale	…
A				
B				
C…				
G				

As mentioned before, the database gives us information about the characteristics of the relationships and of the partners (from the interviewed firm's point of view). Unlike the methodology used in other studies on cooperation, the Erie survey does not allow us to distinguish between types of partners (i.e. cooperation between competitors versus cooperation between clients and suppliers). Nevertheless, the survey informs us on the nature of the partners, based on their R&D activities: firms engaged in R&D, firms not engaged in R&D, consortium and academic partners. The relational variables are used to build a typology of the different forms of cooperation. The second types of variables will allow us to test whether the partners' characteristics contribute to explaining the diversity of the relationships. For this second stage of our analysis (Section 4), we also use three other databases. The R&D database, which comes from the French Ministry of Education and Research, provides information on firms' research expenditures in 2002. The Annual Survey of Firms (EAE) conducted in 2002 provides us with information about the individual characteristics of firms such as size, sector, turnover and location. Finally, the Community Innovation Survey (CIS3) provides information about spillovers and appropriability conditions. Merging the new sample of relationships with those databases, we obtain a final sample of 3072 relationships.

3. Exploring the diversity of collaborative R&D: A multidimensional analysis

As mentioned in Hagedoorn et al. (2000), a unified framework to analyze R&D collaboration is not available. In this section, we explore the various forms of collaboration in order to gain a better knowledge and understanding of R&D collaboration. Indeed, there are mainly two empirical ways of empirically examining R&D relationships. One consists in examining the cooperation partners (public with public actors vs. private with competitor, customer or supplier…). Another one focuses on the level of formality of these relationships (existence of a contract or not). Our objective is to study the particular combinations of those various dimensions, which are not independent (Hagedoorn et al., 2000)

3.1. R&D collaboration characteristics

There are many different forms of R&D collaboration and each form is governed in a particularly way. We briefly discuss the various characteristics of these relationships. Indeed, the various dimensions of the R&D collaboration concern the existence (or not) of a contract, the short vs. long term perspective of the cooperation or its market vs. research orientation; the types of R&D cooperation formal arrangements (joint venture; joint research; customer-supplier relationships …); the duration; the level of partners' involvement in the relation through the existence of various specific investments (mode of communication for example).

Following the transaction cost approach, a form of cooperation is chosen in order to minimize transaction costs. According to Brockhoff (1992), the presence of a contractual agreement is significantly related to the perception of high transaction costs: the higher the transaction costs, the less frequent cooperation with no contractual agreement. The frequency of interactions or usual transactions and the specificity of assets are other factors that increase transaction costs (Williamson, 1979). According to Becker and Dietz (2004), formal R&D agreements are established when no permanent market relations exist. The number of partners, their location (national vs. international partners), and the stage in the life cycle of the product has a critical influence on those transaction cost dimensions (Brockhoff, 1992). Contractual agreements also allow the firms to reduce uncertainty and to reduce the risk of opportunistic behavior among partners. Thus, in highly strategic contexts, collaboration partnerships are governed by formal contracts, whereas in the context of commercial relations (non strategic) there are no such contracts (Forsgren and Johanson, 1992). The types of contracts selected also vary a great deal depending on the types of incentives involved (for instance, majority vs. minority ownerships, incentive contracts such as licensing… see, Huber, 2003).

Hagedoorn (1993) proposes a richer taxonomy of the different forms of formal contractual agreements depending on the actors' objectives: short-term technological achievement vs. long-term positioning (and mixed strategy). In the first case, firms engage in simple contracts while in the second case, complex inter-organizational modes of cooperation are necessary.

Complex or strong modes of governance concern joint ventures, research corporation, joint R&D or direct investments. On the other hand, short term objectives such as technology achievement or cost minimizing are achieved in the context of simple contractual arrangements (R&D pacts), technology exchange or transfer, or customer-supplier relations. Complex modes of R&D cooperation are chosen by firms that have wider objectives (market access, technology-related motivation) and which have long term perspectives since they are complex to manage. Simple contractual arrangements are better suited for simple applied research objectives. Nevertheless, even if an important variety of R&D cooperative agreements exists, the latter can be divided into two categories: contractual vs. complex arrangements (Hagedoorn, 1993). Thus, the short vs. long-term perspectives of the cooperation should be considered. The proximity to the market of the outputs the research results in (products, patents, publication …) should inform us on the firms' positioning.

On the other hand, very little is known about informal partnerships (Hagedoorn et al, 2000; Bönte and Keilbach, 2005). Nevertheless, we expect that when the partners have a short term research objective, their relationships are rather informal. For instance, according to Hall et al (1998) "generally, in these relationships, the university is serving in the role of a short-term project-specific research subcontractor" (Hall et al., 1998).

Another related facet that should be taken into account is the duration of the relation. According to Becker and Dietz (2004), "the duration of R&D cooperation and the intensity of resource exchange could inform on the decision-making processes and the mechanisms for generating synergies and cross-fertilization effects".

Those dimensions are not independent (see Figure 1). Nevertheless, there are no a priori univocal relations between them: for example, "there is no strict correlation between modes of cooperation and their strategic or cost-economizing content" (Hagedoorn, 1993). For this reason, we believe that a typology is well-suited to our objectives. Indeed, this method enables us to avoid presupposing the existence of relations between those different variables.

Our database allows us to define several variables related to the relationships' characteristics that we will use in order to build the typology of the relations. The variable **Research** defines five possible types of research: Common research, sub-contracting, multi-partnerships (consortium), management of a common structure and other[2]. The variable **Duration** points out if the relation lasts less or more than five years[3]. A group of dummy variables describes the organizational arrangements of the relationship. The variable **Contract** indicates if a contract was signed between the partners. The variable **ICT** specifies if a specific communication mode is built and used by the partners. The variable **Investment** shows

[2] This latter type is quite problematic, as we do not have any information on the modality "other".

[3] We would have prefer to be able to distinguish three-year-relations, 3 to five years relations and the ones that last more than five years, as it seems more precise and more linked to the reality of the relationship. However, the survey asks for three types of duration: less than one year, less than five years and more than five years. Descriptive statistics show that the only pertinent distinction is more or less than five years.

whether a specific investment is done by one of the partners. This also goes along transaction cost theory (Williamson, 1991). When one of the partners makes an investment into the relationship, one can assume that the latter is intended as a long term relationship; indeed, the specific asset is not easily re-usable without important sunk cost. The variable **Comm** indicates whether the cooperation generates important interactions during the relation to reach the fixed goals. The variable **Balanced** specifies if the relation is considered balanced by the interviewed firm. Finally, the variable **Outputs** indicates whether the results of the cooperation are rather market oriented (new product or process), or more fundamental (co-publication, patent, prototype, software) or both of them.

3.2 Methodology

To study the heterogeneity of R&D collaborations, we have performed a Multiple Correspondence Analysis (MCA) on the relational variables discussed above and presented in detail hereafter, followed by an ascendant hierarchical classification (AHC).

MCA represents a well suited methodology for exploring qualitative data and for analyzing the relations between more than two categorical variables that can be presented in multi-way contingency tables. More precisely, the total variation of the data matrix (the inertia) is computed by the usual Chi2-statistics which measures the distance separating the original distribution from the one insuring the independence of the variables. Three main criteria can be used to retain the most discriminating axes for the analysis: the percentage of inertia explained; the marginal contribution of the axes to the explained inertia; and the general meaning of the axis which will constitute the new synthetic variables (Benzécri, 1992). Since the more axes are retained for the AHC, the higher the intra-class variance, researchers often only keep two or three axes for their analysis.

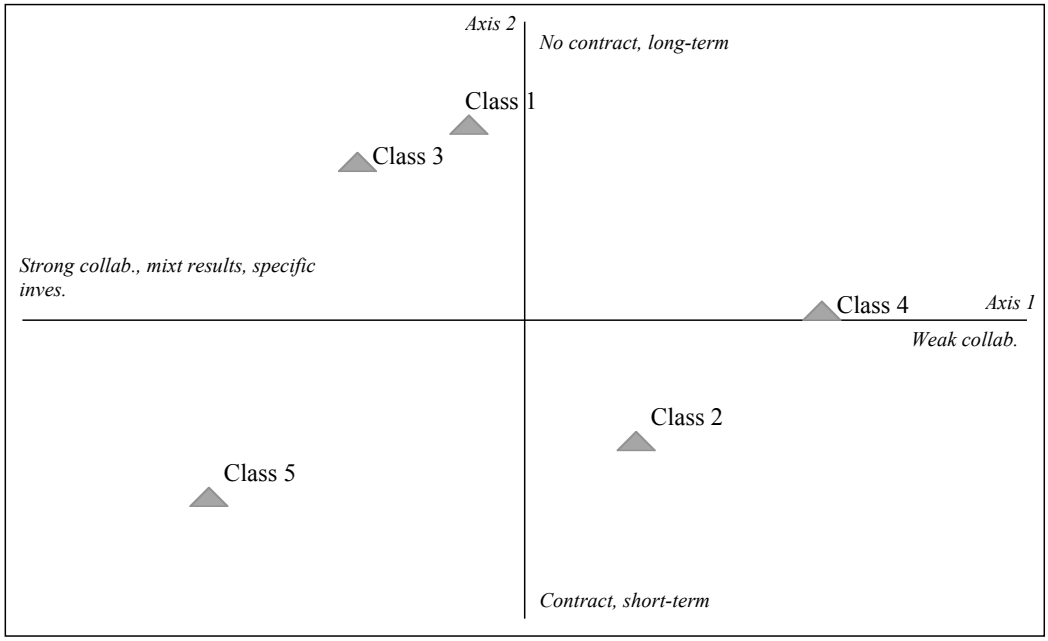
In a second stage, the individuals' coordinates on the selected axes are the inputs for the AHC, which is used to split the population into homogeneous groups. The AHC algorithm proceeds as follows: at each step pairs are formed by merging the closest clusters in order to minimize the within-type variance and to maximize the between-type variance. The comparison of these two values (intra vs. inter-class variances) is the criterion used to select the number of classes to be retained. Finally, in order to highlight the main characteristics of the individuals by class, the coordinates of the class centers are represented on the axes determined in the MCA.

3.3 Results

Our objective is to study the diversity of the R&D cooperative relationships in France. For this purpose, we have performed a multiple correspondence analysis (MCA) on the variables

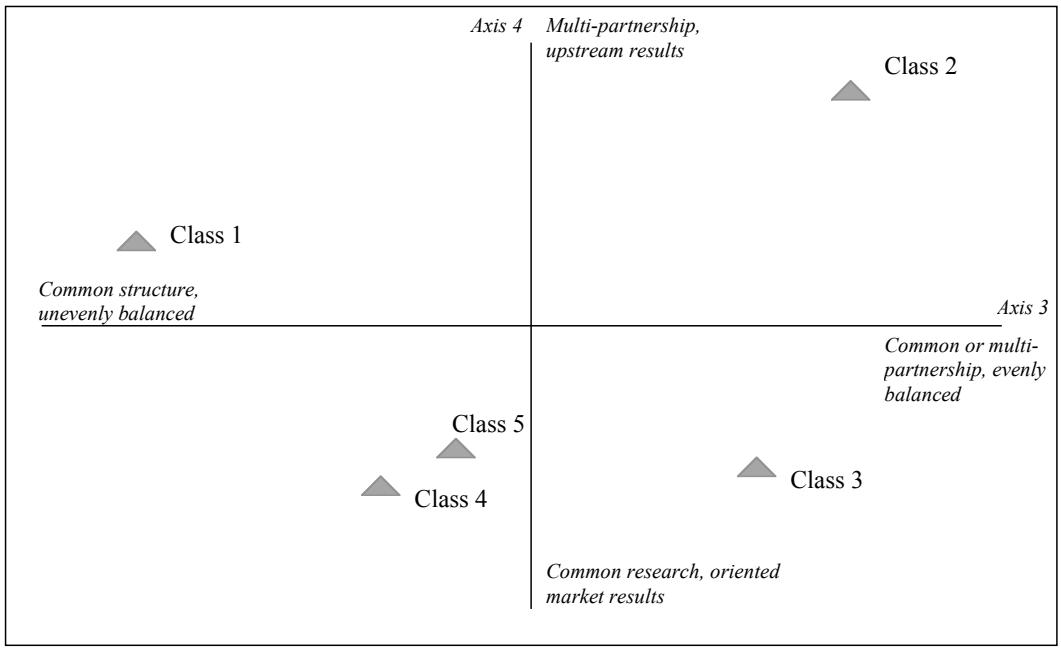
characterizing the 3297 relations constituting our population. Four axes explain 41.9 % of the total inertia of the data. The coordinates of the individuals (relationships) of the sample on these axes have enabled us to create an ascending hierarchical classification (AHC) that results in the division of the population into five homogeneous classes (with an intra-class variance of 46 % and an inter-class variance of 54 %). In other words these classes comprise firms with similar profiles in terms of the variables retained for the analysis. Results show the diversity of the inter-firm relations. The centers of the five classes obtained may be represented on the four axes space of the MCA as presented below.

Figure 1. The projection of the five classes' centers on the first two axes of the MCA.



As Figure 1 shows, the first axis (12.2% of the total inertia) accounts for the intensity of the collaboration between the partners. It opposes the relationships characterized by important joint efforts on both partners' part from the relationships that are not (i.e. weak collaborations). Moreover, a strong collaboration relationship is associated with the existence of specific investments, a specific mode of communication and mixed results in terms of proximity to the market (i.e. process or product innovations and co-publication or patents). A weaker collaboration is associated with a subcontracting relation. On this axis, the fourth class is strongly opposed to class 5. The second axis (11% of the inertia) is opposed to the short term (< five years) relations also characterized by the existence of a (written) contract to the long-term relations which do not entail the signature of a contract. On this axis, classes 5 and 2 are opposed to classes 1 and 3.

Figure 2. The projection of the five classes centers on the axes 3 and 4 of the MCA.



The third axe (9.7% of the inertia) accounts for the type of research: common research or multi-partnership opposed to the management of a common structure. It also accounts for the balanced vs. unbalanced nature of the research. It mainly opposes Classes 2 and 3 to Class 1 and to a lesser extent Class 4. Finally, the last axis (9 % of the inertia) accounts for the nature of the outputs (more or less proximate to the market) associated to the nature of the research: common research leading to innovation vs. multi-partnership leading to patent or co-publication. It opposes Class 2 to Classes 3, 4 and 5. We now discuss the characteristics of each class using the analysis of Figures 1 and 2 and Table 4. Then we complement our findings with the analysis of supplementary variables (Cf. Table 5).

Class 1 relationships can be qualified as **long term relationships for the management of a common structure** and represent 14 % of the sample. They are long-term partnerships (as they last more than five years) the objective of which is the management of a common structure (or other type of relations[4]). These are long-term relationships with firms that do not conduct R&D activities, which mainly belong to the same group of companies, and are located in foreign countries. Another important criterion retained to establish the relationship is the guaranty of a long-term relationship. The economic rationale for this relation is based on a group logic, the search for scale economies or the refocusing on the core business/competencies of the firm but not the access to new markets. Logically, such relations result from the decision of the group.

Class 2 relationships can be qualified as **multi-partnerships in upstream research projects** and represent 16.4 % of the sample. They are generally evenly balanced (in the sense that none of the partners imposes its conditions) and short or medium-term (< five years). They

[4] This category is unfortunately not specified in the survey. Nevertheless, as regards the characteristics of this class, we may expect it consists in the deliveries of a service that take place within the group.

mainly consist in fundamental research generally achieved with several partners, within consortium, or with a public laboratory. They tend to focus on upstream research outputs such as patents, co-publications or software. When these partnerships take the form of consortia, they often are European Union projects, such RDFP projects. The main criteria determining the choice of such partners are its/their notoriety, competencies, and technical means. The economic rationale for establishing such relations is the search for flexibility and scale economies. The respondents generally describe this kind of partnership as non strategic. Indeed, they do not involve any specific investments nor any organizational arrangements (i.e. contract).

Table 4. Description of the classes

Classes	**1**	**2**	**3**	**4**	**5**	**All**
Number	459	543	900	775	620	3297
Frequencies (%)	14	16.4	27.3	23.5	18.8	100
Characteristics of the relation (en %)						
Duration (more than 5 years)	73	34	58	36	45	48
Unevenly balanced	39	24	9	60	32	32
Strong cooperation	33	50	62	12	63	44
Specific communication mode	11	10	5	5	31	12
Specific investment	13	14	5	4	44	15
Existence of a contract	30	38	16	29	77	36
Results :						
- Upstream outputs (patents, co-publ., software)	17	56	0	0	0	11
- Oriented-market results (new products, process or prototypes)	60	29	81	91	41	65
- Both	23	15	19	9	59	24
Type of the relation :						
- Common research	2	17	81	17	41	37
- Sub-contracting	3	29	19	83	58	41
- Multi-partnership	3	53	0	0	0	9
- Management of a common structure	47	0	0	0	0	7
- Other	45	1	0	0	1	6

Source: Erie Survey (authors' calculation)

Class 3 relationships are characterized by **common market-oriented research** and represent 27.3 % of all relationships and so are the most frequent. They are characterized by common market oriented research projects leading to the development of new products or processes. They consist in long-term (> five years) and balanced relations. These relations also rest on a strong cooperation in terms of interactions and exchange. Nevertheless, they do not involve

specific investments, nor any specific communication means, and not governed by contracts either. Firms that get involved in this type of relationship generally do so with firms that perform R&D activities. The partner is often part of the same group and located in another European Union country. The main criteria retained to establish the relationship are, as in the case of Class 1, a group logic. Moreover, they are rather described as strategic. In the process of innovation, the firms interviewed that are involved in this type of relationship are engaged in the stage of industrial development.

The relationships in Class 4 are essentially **subcontracting relations**. They represent 23.5 % of the sample. They are logically unbalanced relations (one partner imposes its condition to the other). These relations are short or medium-term. Moreover, the relations do not lead to any close cooperation between the parties. Such relationships do not necessitate specific investments or communication means. They lead to oriented-market results. Such relations are formed within the region or within France, and less often with firms that belong to the same group or with laboratories. Nevertheless, geographical proximity is rather not declared as the main determinant of the choice of the partner. The main criteria are: the notoriety of the partner, its price and guaranties in terms of quality (label, certification …). This relationship is not based on risk sharing. Firms establish relations of this type so as to compensate for the absence of internal competencies, skills and equipments in the area.

Relations in Class 5 are **contractual relationships based on a strong collaboration and involvement.** They represent 18.8 % of the collaborations in our sample. The results of these relationships are varied in nature: co-publications and/or patents and new products or processes or prototypes. These relations differ from other classes in that they are characterized by important mechanisms used to facilitate and control the cooperation. Thus, a contract is often signed and a specific investment is made by at least one of the partners. A specific communication mode is adopted. They involve a joint effort of the partners and are therefore based on strong collaboration. Two main characteristics of these relationships are, first of all that the partners share the risks, and second of all that the relationship itself is strategic in nature. Even if these relationships are often achieved with public labs, firms also have an upstream role in the cooperation (research, experimental development). One of the main reasons for the choice of a particular partner lies in the fact that the latter's competencies and technical resources complement those of the firm. The notoriety of the partner as well as the guaranty of a long-term engagement are the other determining criteria of this choice. Firms that develop this type of relationship do so for various economic reasons: such a relationship could enable them to focus on their core competencies/business and so help them to gain access to new markets, compensate for the absence of internal competencies and equipment, or improve their flexibility.

Table 5. Additional variables (contributions to the Chi2)

Classes	Chi^2	1	2	3	4	5
The partner :						
Nature :	***					
- Firm with R&D				+		
- Firm without R&D		++	--	-		
- Consortium or technical center			++	-		-
- Laboratory, associations		--	+	(-)		+
Belonging to the same group	***					
		++	--	++	-	(+)
Location :	***					
- Local						-
- Regional					+	-
- France		-		-	+	+
- Europe			(+)	+	-	-
- Other country		++			--	++
Criteria for its choice :						
- Group	***	++	--	++	--	(-)
- Technical means, know-how, competencies complementarity	***	--	++			+
- Notoriety	***	--	++	--	(+)	++
- Price/Quality	***	-		--	++	
- Geographical proximity	Ns					
- Guaranty of a long term contract/relation	***	++	+	-	--	++
The relation :						
Economic rationale:						
- Group mode of organization	***	++	--	++	-	(-)
- Absence of internal competencies/skills	***	--	(+)	--	++	+
- Absence of equipments	***	--	-	-	++	++
- Search for flexibility	**		++	--		+
- Search for scale economies	***	+	+		--	
- Access to new markets	***	-			--	++
- Focusing on core business/competencies[γ]	***	++	-	(-)	--	++
Role of the firm (respondent) in the relation :						
- Research	***	(-)		(-)	--	++
- Experimental development	***	--	(+)		-	++
- Industrial development	***		--	+	-	+
- Production	***	++	--			+
Shared risk	***			(-)	--	++
Strategic nature of the relation	***		--	+		+

[γ] This variable is provided for 2,353 relationships only.

Source: Erie Survey (authors' calculation)

4. Explaining the heterogeneity of R&D collaborations

The literature underlines that it is necessary to examine the various types of agreements and not just to consider that cooperation always takes the same form. Indeed, agreements reveal important differences in the ways cooperation projects are managed and performed. (Lopez, 2006; Belderbos et al., 2004; Cassiman and Veugelers, 2005). We consider that the cooperation can be simultaneously determined by three types of variables: the economic rationale for the cooperation (the motives), knowledge spillovers and appropriability conditions and finally the partners' characteristics (absorptive capacity, belonging to the same group), contrary to the literature that often study one or two of theses dimensions.

4.1 Motives for participating in R&D cooperation: hypotheses

4.1.1 Economic rationales

The literature in economics and management underlines the diversity of the motives to cooperate. According to the cost transaction theory, cooperation helps reduce opportunism and the risk for the transaction (Williamson, 1991). In the resource based theory, cooperation allows for the transfer of complementary skills (Ciborra, 1991; Mitchell and Singh, 1992…), which cannot be transmitted through market-based transactions. R&D cooperation is then seen as a means to internalize and combine complementary, untradable resources (Barney, 1991). Cooperation is then considered as a mechanism to maximize firm's value through effectively combining the resources of the partners by exploiting complementarities (Kogut, 1988; Hagedoorn et al., 2000). Compared to R&D projects undertaken by individual firms, cooperative R&D projects are thought to reduce research time (Contractor and Lorange, 1988). Cooperation also enables firms to reduce the costs of research by sharing them with the partners. Sakakibara points out that scale-based R&D cooperation requires a relatively clearer understanding of the objective and configuration of a cooperative R&D project: the sources of economies of scale must be identified by both partners before the execution of the project. This means that not all cooperative relationships are motivated by this reason; indeed it is not always possible beforehand to know precisely how the project will proceed and therefore to identify the economies of scale that will be realized. Finally, R&D alliances are also competitive strategies to gain market share, innovative edge, or to build entry barriers (Vickers, 1985).

Thus, various motives for cooperation are discussed in the literature but we do not know if these motives correspond to different forms of cooperation. Besides, as Sakakibara (1997) notices, cost-sharing and skill-sharing motives are not necessarily exclusive even if for the firms interviewed gaining access to complementary knowledge is the most important objective of the project and sharing fixed cost is one of the least important objectives. Tether (2002) shows that firms sometimes cooperate when they face different difficulties. Lopez (2006) emphasizes that cost-risk sharing and, to a lesser extent, complementarities strongly

impact the probability of cooperating whatever the nature of partners (with the exception of competitors). Belderbos et al. (2004) stress that cost constraint motivates cooperation with public research institutes while risk constraint influences cooperation between competitors and between suppliers. We make the hypothesis that the different motives can help differentiate the different types of cooperation, without the motives being exclusive of one another. For instance, a need for complementary skills can be an explanation for all types of cooperation, whereas a lack of equipment is a good explanation for why a firm chooses the subcontracting solution; indeed the firm might not wish to purchase equipment that it will only need temporarily. As for risk sharing, it has a strong impact on upstream research cooperation.

4.1.2 Knowledge spillovers and appropriability conditions

Theoretical industrial organization literature considers that R&D cooperation allows firms to internalize knowledge spillovers (De Bondt, 1996) whether they cooperate with competitors (d'Aspremont and Jacquemin, 1988), customers or suppliers (Atallah, 2002; Inkmann, 2001). Most theoretical models show that a high level of knowledge spillovers increases a firm's probability of cooperating.

However, empirical analyses show different results. Cassiman and Veuglers (2002) who have measured spillovers by the relevance of public information sources (such as patent information) show that the estimated coefficient of their spillovers measure is statistically insignificant for vertical cooperation. Belderbos et al. (2004) demonstrate that the probability of cooperating increases with incoming spillovers when the firm and its partners are similar in nature. For instance, cooperation with a customer benefits from customer spillovers but not from supplier spillovers. Moreover, every type of cooperation benefits from institutional incoming spillovers (that is issued from universities) but not from public incoming spillovers (that is patent, database, trade literature and fairs). Thus, the empirical analysis takes more into account the nature of the partner and shows that the impact is not always verified.

If firms try to increase incoming spillovers, they also attempt to appropriate the benefits of their innovations by controlling information flows out of the firm (Belderbos et al., 2004), in order to reduce outgoing spillovers. Indeed, imperfect appropriability increases the cooperating firms' temptation to free ride on each other's R&D investments (e.g. Shapiro and Willig, 1990; Kesteloot and Veugelers, 1994) and encourages outsiders to free ride on the R&D efforts of the cooperation partners (Greenlee and Cassiman, 1999). Thus firms are likely to take into account appropriability conditions when entering into cooperation agreements with other organizations (Bönte and Keilbach, 2005).

The results of empirical studies on the role of knowledge appropriability on the choice of cooperation relationships are not all similar. Belderbos et al. (2004) show that outgoing spillovers do not have any impact on the probability to cooperate, whatever the partner.

Kaiser (2002) studying the German service sector shows that measures of outgoing spillovers are not statistically significant on the probability to cooperate. Hernan et al. (2003) find that the effect on cooperation of the level of appropriability is statistically significant and negative.

Cassiman and Veugelers (2002) propose two measures of appropriability. They show that a greater appropriability of results of the innovation process (lower outgoing spillovers), measured by firm-specific protection mechanism (such as secrecy) increases the probability of cooperating with customers or suppliers but is unrelated to cooperative agreements with research institutes. The industry-specific legal protection mechanisms (such as patents) have no impact on the probability to cooperate.

The diversity of the results suggests that appropriability and incoming spillovers can have different impacts depending on the type of partners. It does not allow us to propose a robust hypothesis.

4.1.3 Firms Absorptive capacity (R&D, size)

The size of the firm

In the economic literature, the size of the firm partly explains the latter's strategies and behaviors. Thus, Link and Bauer (1987), Vonortas (1997), Fritsch and Lukas (2001), Tether (2002) find that the firm's size, measured by the number of employees, increases the propensity to cooperate. We can then expect to find this result in our model. However, this relation is not so obvious. Indeed, small firms might have the greater need for co-operative agreements because in general they have fewer internal resources. But whilst large firms have greater internal resources, they are also likely to engage in a wider range of activities, including some that might benefit from cooperation (Tether, 2002). The firm's size itself therefore gives little indication as to whether or not firms might engage in cooperative arrangement. Rather it is because the size of the firm proxies for (market) power that it is likely to influence the configuration of such arrangements (Tether, 2002). Moreover, Kleinknecht and Van Reijnen (1992) confirm that this hypothesis must be considered with caution as their results show that the firm's size has no significant influence on the probability of R&D cooperation. However, we expect that big firms are more likely than small firms to undertake upstream research cooperation, as this type of research often requires more investment and equipment.

R&D intensity

The second characteristic we consider is the R&D intensity. We can expect R&D intensity to impact positively on the probability of cooperating. One of the reasons for this is that R&D intensity is indicative of firms' ability to absorb external knowledge and to identify new technological opportunities (Negassi, 2004). Thus, firms conduct R&D partly in order to increase their absorptive capacity and to take optimal advantage of their environment. They

can do it through R&D co-operation. Becker and Dietz (2004), Negassi (2004) and Fritsch and Lukas (2001) show a positive impact of R&D intensity on R&D cooperation. Tether (2002) and Belderbos et al. (2004) reach the same conclusion when they distinguish several types of partners. However, Belderbos et al. (2004) note that the R&D variable is not significant in the equation for cooperation with competitors. Moreover, there are important differences between cooperation types in terms of coefficients.

As in the case of the firm' size, empirical results vary. Indeed, König et al. (1994) find no significant relationship between R&D intensity and cooperation while Vonartas (1997) concludes that cooperation is linked to R&D intensity in only one of his five industrial sectors. Kleinknecht and Van Reijnen (1992) also find a positive impact of R&D levels only on cooperation with foreign R&D institutes. More recently, Lopez (2006) shows that R&D intensity has no significant impact on the probability of cooperating.

4.1.4 Other characteristics of a firm: Belonging to a group

Belonging to a group may influence the results related to the size of the firm – results outlined above. Firms that belong to larger groups are, on the one hand, able to draw on resources from within their group and might therefore, not need to seek as many resources externally; on the other hand, firms that belong to groups can draw power, security and prestige from the fact that they belong to a large group and then use it to gain new partners for innovation (Tether p.956). Empirical models find that belonging to a group has a positive effect on the probability to co-operate (Negassi, 2004; Kleinknecht and Van Reijnen, 1992; Tether, 2002). However, Belderbos et al. (2004) and Tether (2002) distinguish firms that belong to domestic group from those that belong to foreign group. Their conclusions concerning the probability to cooperate differ but it is worthwhile noting that both show that belonging to a group has a different influence depending on the type of partners.

4.2 Methodology and variables

The multinomial logit model is seen as a generalization of the binary logit model with a polytomous and unordered dependent variable. It is a non-linear model that enables us to examine the probabilities of the *(m+1)* different values of the dependent variable *y*. The relative choices can be defined as follows:

$$p_j = \Pr(y_i = j) = \frac{\exp(x_i \beta_j^*)}{1 + \sum_{k=1}^{m} \exp(x_i \beta_k^*)} \qquad (1)$$

with $\beta_j^* = \beta_j - \beta_0, \forall j = 1,2,...,m$. This formulation enables us to follow the constraint $\sum_{k=0}^{m} p_k = 1$ and the estimated parameters must be interpreted in relation to the reference group (i.e. to value *m=0*).

The estimation of the model is then performed by maximizing the log-likelihood function with respect to the vector of parameters $(\beta_1,...,\beta_m)$. This function formulated as follows:

$$\log(L) = \sum_{i=1}^{N}\sum_{k=1}^{m} y_{ik} x_i \beta_k - (m+1)\sum_{i=1}^{N} \log\left(1 + \sum_{k=1}^{m} \exp(x_i \beta_k)\right) \quad (2)$$

In our case, the choice between j forms of collaboration is determined by the profit expected by firm (*i*) from this form of cooperation (*j*). Belonging to Class 4 corresponds to the reference value of the explained variable[5].

Appendix A describes the selected explicative variables. The R&D intensity is measured by the logarithm of the R&D expenditures of the firm. We also test the relative importance of internal information used in the innovation process. *Indintsourc* is the mean score of the importance of internal source for innovation (marketing, R&D…) at the industry level. This level of analysis reduces the risk of endogeneity between both variables. The *size* variable is measured by the logarithm of the number of employees. In order to test if the choice of cooperation mode depends on the size of the firms or on the position in the market, we also introduce the market share of the firm. The *group* variable indicates whether the firm is independent or belongs to a French group or to a foreign group. Six variables concerning the motives for cooperation are also introduced. We test the cooperation for economies of scales, for new markets, for competencies, for equipment, for flexibility and finally for risk sharing. In order to better understand the impact of the firm's activities on this decision to cooperate, we also introduce variables to indicate if the firm plays a market driven role, a production and research role or both.

The introduction of spillovers at firm level can generate potential endogeneity problems (Belderbos et al., 2004; Lopez, 2006). Indeed, if spillovers may influence a firm's decision to cooperate, a reverse effect of cooperations on incoming spillovers may also exist since firms may develop cooperative relations with other organizations in order to increase incoming knowledge flows. We then use the spillover variable at the 3-digit industry level. We suppose that the problem of endogeneity is smaller as the strategy of one firm should not strongly modify the industry variable. We build two variables of spillovers: the Indpubsourc variable measures the importance of public sources to innovate, at the industry level such as professional conferences, meetings, journals, fairs and exhibitions. Indinstsourc measures the importance of institutional sources coming from universities and public research organizations. We also include two measures of appropriability. Indprotstrat measures the strategic protection such as secret, complexity, lead time. Indprotleg represents the legal protection. We test their effects at industry level.

[5] Since individuals of our dataset are firms' relations and since a firm can describe several relations, we make use of the cluster option in Stata.

The results of the multinomial logit estimation are presented in Appendix B (Table 6). It should also be noted that a wald test rejects the null hypothesis that these categories can be collapsed (see Appendix B, Table 9) indicating that significant differences between these cooperation strategies exist. We also have tested the validity of the Independence of irrelevant alternatives (IIA) assumption since it is essential for the appropriateness of the multinomial logit model. We have employed a Hausman-type test provided by Hausman and McFadden (1984) which compares the estimated coefficients of a model using all three categories and a subset where one of the categories is excluded (see also, Bönte and Keilbach, 2005). We extended the model with five categories. If the IIA assumption holds, then the estimation of the restricted and the unrestricted model should provide similar estimates. The test suggests that the null hypothesis of IIA assumption cannot be rejected for each of the categories. As the Chi2 is negative when class 2 and class 3 are separately excluded (see Table 10), we performed another Wald test based on seemingly unrelated estimates. The results of this test confirm that the IIA hypothesis is not violated[6].

Finally, Appendix B (Table 7) displays marginal effects for the variables included. These can be interpreted as the percentage point change in the probability of choosing a particular form of cooperation given a 1% deviation from the mean for continuous variables and the percentage point change in the probability of entering a form of cooperation if a dummy variable changes from 0 to 1.

4.3 Results

Table 6 presents the results of the multinomial logit estimation, with Class 4 as the reference class. This means that the significance and sign of the coefficient need to be interpreted relatively to this class. Since such relative probabilities are hard to interpret, we choose to discuss the marginal effects of the explanatory variables on the probabilities of each cooperation type presented in Table 7. We begin with a vertical reading of the table and discuss the determinants and motives of each type of collaboration (4.3.1). Then we discuss the results for each explanatory variable (4.3.2).

4.3.1 Estimation results

The results suggest that the probability of developing a common structure is positively influenced by the existence of shared risk, the level of strategic appropriability and the fact that the firm belongs to a foreign group. Moreover, the probability increases when the firm performs applied research activities as part of the cooperation. However, the probability of choosing a common structure is reduced when firms cooperate in order to gain access to new markets, or to the competences or equipment of the partners. The probability of choosing this

[6] Proofs are available upon request.

strategy is also negatively influenced by the level of R&D. The higher the R&D level, the lower the probability of choosing this strategy[7].

The probability of choosing a multi-partnership in upstream research is positively influenced by the size of the firm and the level of public spillovers at the industry level. Moreover, cooperating in order to realize economies of scale and to compensate for a lack of competencies has a positive impact on this probability. The fact that a firm realizes downstream or mixed activities in the relation reduces the probability of choosing this strategy. We observe the same phenomenon if the firm decides to cooperate in order to compensate for a lack of equipment and if institutional spillovers at the industry level are high. Thus, firms choose a multi-partnership in upstream research when they perform fundamental activities and if institutional spillovers are low. Thus such collaborations are aimed at absorbing knowledge. More precisely, when spillovers are not sufficient, firms cooperate to try to obtain knowledge they can't get freely.

The probability of choosing a common market-oriented research is positively affected by the fact that the firm is active both in downstream and upstream activities. It also influenced by a marginal increase in the level of internal sources at industry level. Cooperating firms benefit from incoming spillovers from partners when they conduct common research projects. Public spillovers, strategic protection as well as the competencies, equipment and flexibility needs have a negative and statistically significant impact on the probability of adopting this strategy. We may suppose that this type of cooperation is realized between competitors as they cooperate to gain access to the partner's internal resources (i.e. internal knowledge). This is in keeping with Belderbos et al.'s results (2004).

Firms seem to adopt subcontracting relationships in order to compensate for a lack of equipment when the legal protection at industry level is high. Critically, these firms are rather small and they do not belong to a group. The choice of this strategy is negatively impacted by the fact that the partners share the risk. Moreover, firms who want to cooperate in order to gain access to new markets or to realize economies of scales have a lower probability of adopting this strategy. These collaborations are generally aimed at benefiting from better price and quality conditions to benefit for better condition of price and quality without risk of knowledge dissemination.

The probability of building a contractual relationship based on a strong collaboration and involvement is positively influenced by the size of the firm, the downward and upward activities and the existence of a shared risk. It is also influenced by certain cooperation

[7] The strong correlation between the common structure and belonging to the same group indicates that the common structure often represents intra-group relations. However we couldn't include the variable group part in our estimation since there is a strong risk of colinearity between the variable group part and belonging to the same group.

objectives such as realizing scale economies, gaining access to new markets, and compensating for a lack of competencies and equipment.

4.3.2 Result discussion

The firm's characteristics

The results show that the R&D level does not have any significant impact on the choice of type of cooperation, with the exception of the common structure. In this case, the less the firms invest in R&D, the more likely they are to engage in a common project. The common structure is mainly done with non-R&D firms. However we can suppose it could be a means for non-R&D firms to jointly develop R&D activities following a strategy that aims to focus on core business or competencies, as suggested in Section 3.

Bönte and Keilbach (2005) show that in supplier-customer cooperations, the level of R&D has a negative impact on the decision not to cooperate but not on the type of cooperation. Thus, our results could suggest that R&D has an impact on the decision to cooperate as shown in Negassi (2004) and Fritsch and Lukas (2001) but not in the forms of the cooperation. Indeed, in the literature, when cooperations are differentiated according to the type of partners, the impact of R&D on the decision to cooperate with one type of partner is not constant.

We propose another measurement of the internal competencies by measuring the internal knowledge sources. It enables us to find out the importance of the firm's other sources of knowledge (i.e. sources other than R&D). Unfortunately we only have the measurement of the internal sources of knowledge at the industry level. The result shows that the level of internal knowledge source is not significant except in the case of common market-oriented research. This means that the choice of a type of cooperation is not based on the firm's level of R&D but that in some cases, this choice is related to the organizational structure of the knowledge transfer within firms. Belderbos et al. (2004) show that internal knowledge flows have a positive impact only on cooperation with supplier or universities.

The size of the firms positively influences the decision to develop a multi-partnership in upstream research and a contractual relationship based on a strong collaboration and involvement. This result confirms our hypothesis on the link between size and upstream research. Firms that realize cooperation on the upstream activities are more likely to be big firms[8]. On the other hand, the size has a negative impact on the decision to subcontract: the subcontracting solution is more likely to be realized by small firms. Our results are in keeping with those provided by the literature, concerning the unstable impact of the size on the decision to cooperate. Indeed, by distinguishing five types of cooperation, we observe the

[8] We have tested the non-linearity effect of the size. The results (available on request) show that there is not such an effect.

diversity found by other studies: positive impact, negative impact or no impact. This confirms the need to make a distinction between the different types of cooperation.

The market share does not have any impact on the type of cooperation. As for R&D, we can suppose that the market share is a more important factor in the decision to cooperate. This result invalidates our hypothesis that the choice of a type of cooperation sometimes depends on the market structure and sometimes on the size of the firm.

The *Group* variable is generally non significant. This means that belonging to a group does not have any influence on the type of cooperation selected. This result partly confirms Tether's results (2002); indeed the *Group* variable does not have any impact on cooperation with supplier and competitors. Belonging to a group does not influence the type of cooperation. However, Tether finds that belonging to a foreign group increases firms' probability of cooperating with customers and that belonging to a domestic group increases firms' probability of cooperating with a university. Similarly, we note that the Group variable has a significant impact in two cases which are worthwhile mentioning. Firstly, firms that belong to a foreign group have a high probability of developing a common structure. We assume that this strategy can be a means, for foreign groups, of setting up a business in France. Secondly, firms that belong to a group (French or foreign) have a low probability of engaging in subcontracting cooperation. In this type of relations, descriptive statistics indicate that firms are either the ones that hire a subcontractor or are the subcontractor themselves. We cannot then conclude that independent firms are mainly subcontractors. However, we can suppose that independent firms perform less R&D activities and that they do not have the capacity to conduct all the stages of research processes. Conversely, these firms can also be good subcontractor in some very specific research.

The activities of the firm in the cooperation project influence the choice of type of relationship. The common structure is realized when firms only provide the market-oriented research. Firms that conduct upstream activities are more likely to choose a multi-partnership in upstream research. When firms perform both activities, they are more likely to undertake a common market-oriented research or a contractual relationship based on a strong collaboration and involvement. This result is not surprising as the type of cooperation is partly determined by the nature of the results. However, one could not predict that the nature of the activities and the nature of the results could be so highly correlated.

We can conclude that the type of cooperation chosen is little influenced by the characteristics of the firms- with the exception of the firm's size and the role of the firm in the relation. This result can be linked to the fact that firms can have different needs, which require different forms of cooperation. We suppose that these variables have a more important impact on the decision to cooperate or to not cooperate.

Motives

Our results confirm our hypothesis that the type of cooperation chosen depends on the reasons that lead the firm to cooperate. The need for scale economies explains a multi-partnership in upstream research and a contractual relationship based on a strong collaboration and involvement. Conversely, it does not have any significant impact on the common structure and common research. Finally, firms that seek to realize scale economies have a lower probability of engaging in subcontracting cooperation. The wish to benefit from scale economies could explain the cooperative relationships that require important investments or those in which an upstream research project is undertaken.

Firms that wish to gain access to new markets are less likely to choose a common structure or a subcontracting relation. They prefer a contractual relationship based on strong collaboration and involvement. The contract can define the rules and the rights of the market-sharing, which can be very important concerning innovation and knowledge.

A shortage of skills can lead firms to choose a multi-partnership in upstream research or a contractual relationship based on strong collaboration and involvement. This reason reduces the probability of opting for a common structure and for a common market-oriented research. The search for complementary skills seems to be related to upstream research cooperation. When firms conduct market-oriented research they do not cooperate because of a lack of competencies.

A lack of equipment leads firms to choose a subcontracting relation or a contractual relationship based on strong collaboration and involvement. It seems difficult to consider these two types of relations as similar. Rather, it seems that when firms do not possess the equipment or the skills they need for a particular project, they opt for contractual relationships with firms that do possess these needed resources. When there is only an absence of equipment, firms prefer the subcontracting option. An absence of equipment would reduce the probability of choosing the three other types of relations.

The wish to increase flexibility does not influence the choice of relationship, except in the case of common market oriented research. In this case, this reason reduces the probability to choose this type of relations. Flexibility which can be an important factor in production does not seem to be important in R&D cooperation choices.

Our results confirm that relations can take different forms according to the determinants of cooperative arrangements for innovation. They contribute to a better understanding of motives of cooperation. Thus cost sharing or the complementarity of skills are not always the main reasons for entering a relationship; it all depends on the types of cooperation. Moreover, our results highlight that the reasons for cooperating are not exclusive, as shown by Sakakibara (1997) and Tether (2002).

Knowledge spillovers

There is little evidence that institutional spillovers at industry level have a significant impact on the probability of choosing one specific type of cooperation. For the most part they have no significant impact on the decision. This result invalidates Belderbos et al's results. (2004). University and research institutes spillovers do not impact on the type of cooperation. We note one exception, as institutional spillovers reduce the probability to choose multi-partnerships in upstream research. This result is surprising as many partners in this type of cooperation are public labs. However, we measure institutional spillovers at the industry level. Our result could then indicate that when firms can easily benefit from institutional spillovers they do not need to cooperate with university.

Public spillovers only have a positive impact on the probability to choose a multi-partnership in upstream research. This result is quite similar to that of Lopez (2006) on the role of public spillovers on cooperation with research institutions. Public spillovers influence negatively the probability of choosing common market-oriented research. This result is very surprising as in the literature we often expect a positive (or non significant) impact of public spillovers. This result can be compared to that concerning institutional spillovers in upstream cooperation. Indeed, as we use a variable at the industry level, when the level of spillovers is high, the need to cooperate could be reduced; free-riding behavior could be more important, as firms know that they will benefit from spillovers anyway. Here the spillovers occur further downstream than in the previous case. Finally other types of cooperation are not influenced by public spillovers. This confirms Belderbos et al. (2004)'s results. The importance of firms' internal sources in its capacity to innovate, calculated at the industry level (Indintsourc) only has a strong positive impact on the probability to engage in a common research.

Strategic protection at the industry level positively influences the probability of developing a common structure. In this case, the firm is able to protect its knowledge. Bönte and Keilbach (2005) find a similar result for firms that develop formal cooperative relationships. Strategic protection has a negative impact on the probability to choose common market-oriented research. In the literature, strategic protection only has a negative impact on the decision not to cooperate (Bönte and Keilbach, 2005). The other types of cooperation are not impacted. This result differs from those provided by literature (Lopez, 2006) but this might be due to the fact that we use industry data.

Legal protection at the industry level has mainly no impact on the probability to choose one type of cooperation. This confirms the results proposed by Bönte and Keilbach's (2005), Belderbos et al (2004) and Lopez (2006). However, legal protection has a positive impact on the probability of engaging in subcontracting cooperation. In a context where legal protection is high, subcontracting is a privileged option (it is not a risky strategy since if sensitive knowledge or know how are protected, the risk of opportunism by the subcontractor is reduced).

Finally, we suppose that sector-based specificities could play an important role in the choice of the type of cooperation. Indeed, the variables defined at the industry level have, in four of the classes, the strongest impact on the choice of the collaboration mode. Further research in this direction is needed.

5. Conclusion

In this paper, we have investigated the different types of R&D collaborations and have shed some new light on their determinants and motives. To this aim, we have made use of a recent French survey on firms' research and innovation relations. We first showed the heterogeneity of such relations thanks to a typology on their characteristics: nature of the partnership (common research, sub-contracting, multi-partnership, management of a common structure), type of research (market-oriented, research-oriented, mix), its duration (short vs. long term), organizational arrangement (contract, specific investments). Five classes of collaborations have been obtained from the particular combinations of these relational characteristics:

- long-term relationships for the management of a common structure,
- multi-partnerships in upstream research,
- common market-oriented research,
- subcontracting relations,
- contractual relationships based on strong collaboration and involvement.

Using a multinomial logit estimation, we explain how this diversity of partnerships is connected to some individual attributes of the firms, their market, or sector (IS, appropriability…). Concerning traditional factors, we show that the choice of a type of cooperation is mostly not determined by R&D expenditure. Our results also confirm the literature's results on the unsteady impact of the size which positively influences the choice for a multi-partnership and a contractual relationship based on a strong collaboration. It negatively influences the choice of a subcontracting relation. We also find no evidence of the influence of market competition. Moreover, a non negligible percentage of R&D relationships that take the form of a common structure develop among firms that belong to the same groups (and are often located in different countries). When examining the motives to participate in the relation, we find that the search for scale economies explain the development of relations that involve important involvement and investments. The search for equipments is a strong motive to subcontract. Firms looking for access to new markets prefer contractual relationships based on a strong collaboration and involvement. A lack of competencies leads firms to choose a multi-partnership in upstream research or a contractual relationship based on a strong involvement in it.

With respect to appropriability conditions and knowledge spillovers at the industry level, we show that institutional spillovers have no impact on the choice of cooperative relationship, except on the choice of upstream research multi-partnerships on which they have a negative

impact (while public spillovers have a positive influence) . Strategic protection has a negative impact on the probability to choose common research. Legal protection has no impact on the probability to choose one particular type of cooperation, except on the probability to choose subcontracting relationships. We also tested the influence of the geography on the relations but couldn't find any significant effects. The proximity of the partner is never a main determinant for the choice of the partner. We note that subcontracting relations are often national or regional while the partner for the management of a common structure is often a affiliate of a foreigner group.

All in all, our results show that there is an interest in disaggregating R&D cooperation. Indeed, there are important differences in the motives and determinants of the different types of cooperation. Thus, R&D collaboration appears to be a much more sophisticated phenomenon than literature generally suggests. These results call for further research. Indeed, now that we have identified different types of cooperation, it is necessary to wonder about the complementarities between these relations. For this purpose, we propose to analyze the different types of relationships that firm can develop and their impact on innovative performance. Moreover, beyond the bilateral relation, the network of each partner constitutes an element of choice. This also constitutes a challenging direction for future research.

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Appendix A. The variables of the multinomial logit

Explained variable	*Definition*	*Derived from :*	*Mean (Std.*
Typcoop	5-modalities variable, obtained through a typology (cf. Section 2)	Erie survey 2002 - Authors' construction	
Explicative variables			
At the firm level			
R&D	Logarithm of R&D expenses	R&D survey 2002	3.968 (4.19
Size	Logarithm of number of employees	Erie survey 2002	5.198 (1.56
Part group	1 if the firm is part of a domestic group, 2 if the firm is part of a foreigner group, 0 otherwise.	Financial Links 2002	
Market shares	Share of the company's total sales on total sales of the industry.	Erie/EAE 2002	0.046 (0.11)
Risk	Shared risk in the relation		0.128 (0.33)
Role of the firm in the relation			
• Market oriented	Market oriented role of the firm (industrial development and/or production).		
• Mixed	Mixed role of the firm (both industrial development and/or production and research and/or experimental development).		
Motives for the formation of the relation			
• Scale economies	1 if the search for scale economies is an important motivation		0.150 (0.35)
• New markets	1: access to new markets.		0.228 (0.42)
• Competencies	1: search for complementary competencies.		0.405 (0.49)
• Equipments	1: absence of equipments.		0.205 (0.40)
• Flexibility	1: search for flexibility		0.136 (0.34)
At the firm's industry level			
Indinstsourc (Institutional incoming spillovers)	Mean score at the firm's industry level* of the importance of universities and non-profit research institutions as source of knowledge for innovation.		1.451 (0.65)
Indpubsourc (Public incoming spillovers)	Mean score at the industry level* of the importance of professional conferences, meetings, journals, fairs, exhibitions as source of knowledge for innovation.	CIS3 survey (2000)	2.186 (0.33)
Indintsourc (Internal sources)	Mean score at the industry level* of the importance of internal source for innovation.		2.358 (0.12)
Inprotstrat (Strategic protection)	Mean score at the industry level* of effectiveness of secrecy, complexity and/or lead time as a protection measure of innovation.		0.599 (0.22)
Indprotleg (Legal protection)	Mean score at the industry level* of effectiveness of patents and registration of brands as a protection measure of innovation.		0.488 (0.18)

- 3-digit Nace.

Appendix B. Results

Table 6. Results of the multinomial logit estimation

Cooperation form (Class 4: subcontracting - Ref)	Class 1 Common structure	Class 2 Multi-partnerships	Class 3 Common research	Class 5 Contractual research
Log R&Dexp	- 0.619***	- 0.006	- 0.009	0.006
Size	0.614	0.153**	0.025	0.143**
Part group				
- Domestic	0.483**	0.281	0.347**	0.308*
- Foreigner group	0.698***	0.087	0.417**	0.332
Market shares	1.301*	0.592	0.551	0.715
Risk	0.489**	0.345	0.227	0.930***
Role of the firm in the relation				
- Market oriented	0.338*	- 0.388*	0.070	- 0.126
- Mixed	0.428*	0.291	0.724***	0.918***
Motives				
- Scale economies	0.474**	0.715***	0.441**	0.728***
- New markets	- 0.355*	0.249	0.153	0.762***
- Competencies	- 0.559***	0.111	- 0.345***	0.322**
- Equipments	- 0.951***	- 0.532***	- 0.532***	0.099
- Flexibility	0.076	0.191	- 0.362*	0.244
Indinstsourc	0.044	- 0.321	0.284	0.239
Indintsourc	0.064	- 0.676	1.927***	0.154
Indpubsourc	- 0.248	1.621***	- 0.274	0.336
Inprotstrat	1.191*	0.947	- 0.314	0.401
Indprotleg	- 1.701**	- 1.291**	- 1.295**	- 0.653
Constant	- 0.612	- 2.794	- 3.760**	- 3.396*
Number of observations		3072		
Wald Chi2 (72) (Prob>Chi2)		414.39 (0.000)		
Pseudo R2		0.0569		

NB. Standard errors are adjusted for 1626 clusters (firms).
*Significant at 10% level: *; 5% level: **; 1% level: ***.*

Table 7. Marginal effects after the multinomial logit

Cooperation form (Class 4: ref)	Class 1 Common structure	Class 2 Multi-partnerships	Class 3 Common research	Class 4 Subcontracting	Class 5 Contractua research
Log R&Dexp	- 0.006***	0.001	0.000	0.002	0.003
Size	- 0.001	0.014*	- 0.011	- 0.015**	0.014*
Part group					
- Domestic$^{\sigma}$	0.028	0.002	0.023	- 0.061**	0.007
- Foreigner group$^{\sigma}$	0.056**	- 0.032	0.035	- 0.065**	0.006
Market shares	0.096	0.005	- 0.001	- 0.130	0.029
Riskσ	0.012	- 0.007	- 0.045	- 0.080***	0.121***
Role of the firm in the relation					
- Market oriented$^{\sigma}$	0.047***	- 0.058***	0.026	0.004	- 0.019
- Mixed$^{\sigma}$	- 0.010	- 0.033*	0.064**	- 0.104***	0.083***
Motives					
- Scale economies$^{\sigma}$	0.001	0.044*	- 0.006	- 0.093***	0.053*
- New markets$^{\sigma}$	- 0.062***	0.006	- 0.015	- 0.046**	0.118***
- Competencies$^{\sigma}$	- 0.058***	0.032*	- 0.072***	0.020	0.078***
- Equipments$^{\sigma}$	- 0.069***	- 0.033*	- 0.060***	0.078***	0.084***
- Flexibility$^{\sigma}$	0.010	0.033	- 0.092***	- 0.000	0.049
Indinstsourc	- 0.004	- 0.065**	0.059	- 0.018	0.029
Indintsourc	- 0.054	- 0.188	0.417***	- 0.113	- 0.060
Indpubsourc	- 0.059	0.228***	- 0.141**	- 0.050	0.022
Inprotstrat	0.116*	0.106	- 0.175*	- 0.068	0.020
Indprotleg	- 0.100	- 0.059	- 0.107	0.217**	0.049
Predicted (observed)	0.1293 (0.1365)	0.1624 (0.1643)	0.2891 (0.2743)	0.235 (0.2364)	0.184 (0.18

*NB. (σ) dy/dx is for discrete change of dummy variable from 0 to 1. Significant at 10% level: *; 5% level: **; 1% level: ***.*

Table 8. Wald tests for independent variables

Log R&Dexp	11.291 **
Size	9.342 *
Part group	
- Domestic	7.300
- Foreigner group	12.802 **
Market shares	3.325
Risk	27.293 ***
Role of the firm in the relation	
- Market oriented	16.307***
- Mixed	30.892 ***
Motives	
- Scale economies	14.686 ***
- New markets	36.750 ***
- Competencies	36.665 ***
- Equipments	42.882 ***
- Flexibility	11.764 **
Indinstsourc	5.800
Indintsourc	10.665 **
Indpubsourc	23.866 ***
Inprotstrat	6.373
Indprotleg	8.881 *

Table 9. Wald test of the Null that respective categories can be collapsed

Categories tested	Chi2	Df	P>Chi2
1-2	116.320	18	0.000
1-3	58.213	18	0.000
1-4	108.065	18	0.000
1-5	142.443	18	0.000
2-3	82.123	18	0.000
2-4	104.194	18	0.000
2-5	68.205	18	0.000
3-4	88.159	18	0.000
3-5	98.403	18	0.000
4-5	139.718	18	0.000

Table 10. Hausman tests of IIA assumption

Omitted	Chi2	Df	P>Chi2	Evidence
1	7.564	57	1.000	for H0
2	-1.567	57	1.000	for H0
3	-1.271	57	1.000	for H0
5	45.806	57	0.856	for H0

NB: H0: Odds (Outcome-J vs Outcome-K) are independent of other alternatives.